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August 2007

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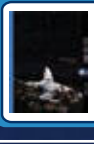

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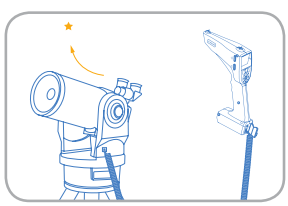

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Astronomy

VOL. 35, NO. 8

The world's best-selling astronomy magazine

august 2007

NASA/JHUAPL/SwRI; COLOR AND STARS BY SIMON JENKS

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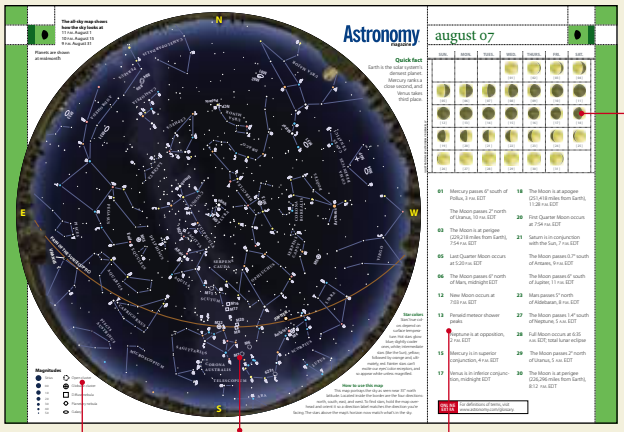

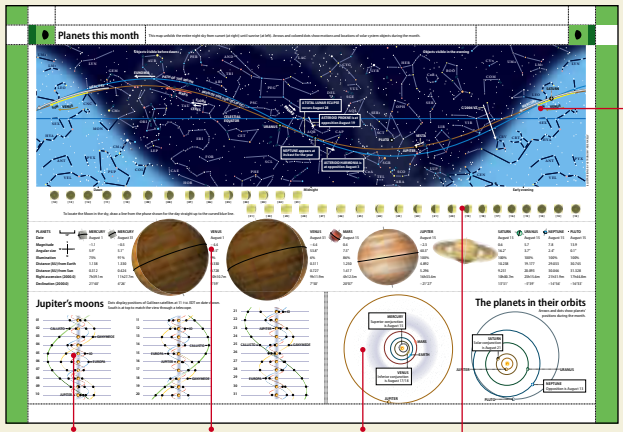

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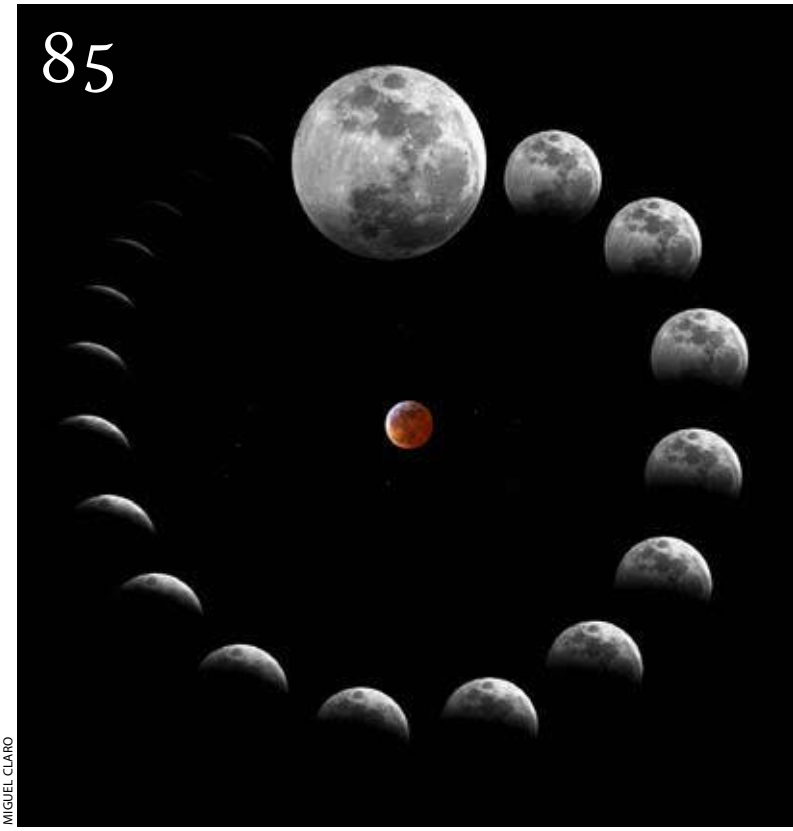

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BY DAVID J. EICHER

New Horizons dazzles scientists

En route to Pluto, NASA's New Horizons

spacecraft gave planetary scientists a whopping side benefit recently when it whizzed past Jupiter and its moons. Launched in 2006, the sleepy spacecraft perked up with an impressive burst of science imaging and data collection as it gave astronomers new views of the jovian system. Highlights included incredibly detailed images of Io, with its active volcanoes spouting geysers into space; tiny satellites shepherding particles along thin tracks in the planet's rings; views of the Earth-sized "Red Spot, Jr."; and high-resolution plates of Jupiter's disk, showing magnificent clouds.

In an *Astronomy* magazine exclusive, Principal Investigator S. Alan Stern writes our story on the flyby, "Jupiter up close and personal" (page 28). In addition to his leadership role in Pluto exploration, Stern, a member of this magazine's editorial advisory board, was recently named associate administrator of NASA's Science Mission Directorate. The words of this preeminent Pluto scientist — accompanied by beautiful and inspiring pictures — give you an exclusive wrap-up on everything New Horizons found at Jupiter. Before writing this story, Stern provided Astronomy.com with a blow-by-blow account of the mission in a blog he wrote for our web site. You can find these posts at www.astronomy.com/newhorizons.

The spacecraft reached its closest approach to Jupiter, 1.4 million miles (2.25 million kilometers), February 28, 2007. "Aside from setting up our 2015 arrival at Pluto, the Jupiter flyby was a stress test of our spacecraft and the team, and both passed with very high marks," says Stern.

Among the most exciting photos taken by the spacecraft — shown in a press conference May 1, 2007 — were images of Red Spot, Jr. This second-largest storm on Jupiter, which formed when three smaller storms merged over the past decade, spans about 70 percent of Earth's diameter. Oddly, about a year ago, it began turning reddish. "This is the best look ever of a storm like this in its infancy," says Hal Weaver, Johns Hopkins University astronomer and New Horizons project scientist.

Of the four Galilean moons, New Horizons focused primarily on Io, a most dynamic satellite with such intense volcanism, it ranks as the most active body in the solar system. New Horizons' cameras captured areas of intensely bright lava scattered across the moon's surface. The most dramatic views were those of the volcano Tvashtar, which shot a fountain of lava 200 miles (320 km) into space. New Horizons captured the moon's dramatic eruptions above the moon's limb.

Many other surprises awaited New Horizons' astronomers as their spacecraft whizzed past Jupiter and its family of moons. For the full story, see Stern's article, which will no doubt leave you impressed with what a spacecraft can do as a dry run on its way to the real job.

Yours truly,

David J. Eicher
Editor

Astronomy

Volume 35, Number 8

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Heavenly bliss found in Indiana

Thank you for your Messier marathon list

on Astronomy.com and for podcasting Glenn Chaple and Phil Harrington's discussion, which I found educational and valuable.

Living in Chicagoland is tough for an amateur astronomer. To see a dark sky, you have to travel several hours. Thanks to your podcast, I took up the challenge to drive to a remote sky: I traveled 2 hours south to Willow Slough Wildlife Area in Indiana.

Using your list, I completed 100 out of 109 Messier objects. I missed: M74, M14, M16, M55, M15, M2, M72, M73, M30.

The closer it was to sunrise, the harder it was to keep going. I managed to finish Sagittarius but missed M55, sinking into the morning sky.

Was it worth swollen knees, pulled back muscles, and red eyes? Totally! I feel proud and satisfied. I finally got those objects that have been hiding from me in a suburban sky.

All the objects looked spectacular, and I fell in love with a dark sky. I almost don't feel like using my backyard for observing anymore. — **MARCIN KLAPCZYNSKI,** CHICAGO

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Questioning cosmology

When I got the May 2007 *Astronomy* with the cover line "Cosmology's 5 big things you need to know," I couldn't wait to dive in. After reading the article, however, I think you could have saved a lot of ink by saying the answers to most of these questions are many theories, hypotheses, and guesses. In truth, we haven't the foggiest notion. — **BUD LAURENT,** ST. AUGUSTINE, FLORIDA

SPIRAL GALAXY M77 in Cetus is the first object to track down during a Messier marathon. FRANCOIS AND SHELLEY PELLETIER/ADAM BLOCK/NOAO/AURA/NSF

Talking shop

In Michael E. Bakich's "An easy guide to astro-speak" (April 2007), 1 AU is explained as one astronomical unit (92,955,807 miles), and the schematic shows it from the Sun's surface to Earth's center.

I want to know whether 1 AU is measured between the bodies' centers or from one surface to the other's center. — **NOZOMU KANEDA,** KOBE, JAPAN

An astronomical unit is a theoretical distance, but, if astronomers did measure it, it would be the average distance between the centers of the Sun and Earth.

Shifty redshift

The formula for determining redshift (z) in Scott Dodelson's "Seeing the red limit" (May 2007) yields a negative value for the "z" of the Sombrero Galaxy (M104), which the article says is receding from us. Although the next sentence indicates a positive value is required. — **W. E. GATCHELL,** ENFIELD, CONNECTICUT

Astronomy *regrets the error. The terms "observed" and "expected" were swapped where the article discusses computing redshift.*

It should have read: "Astronomers divide the observed wavelength by the expected wavelength and then subtract 1 to get the redshift value."

We welcome your comments. Send letters to Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; e-mail to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

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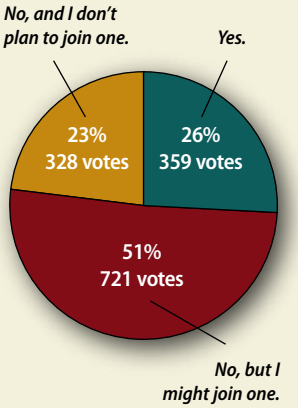

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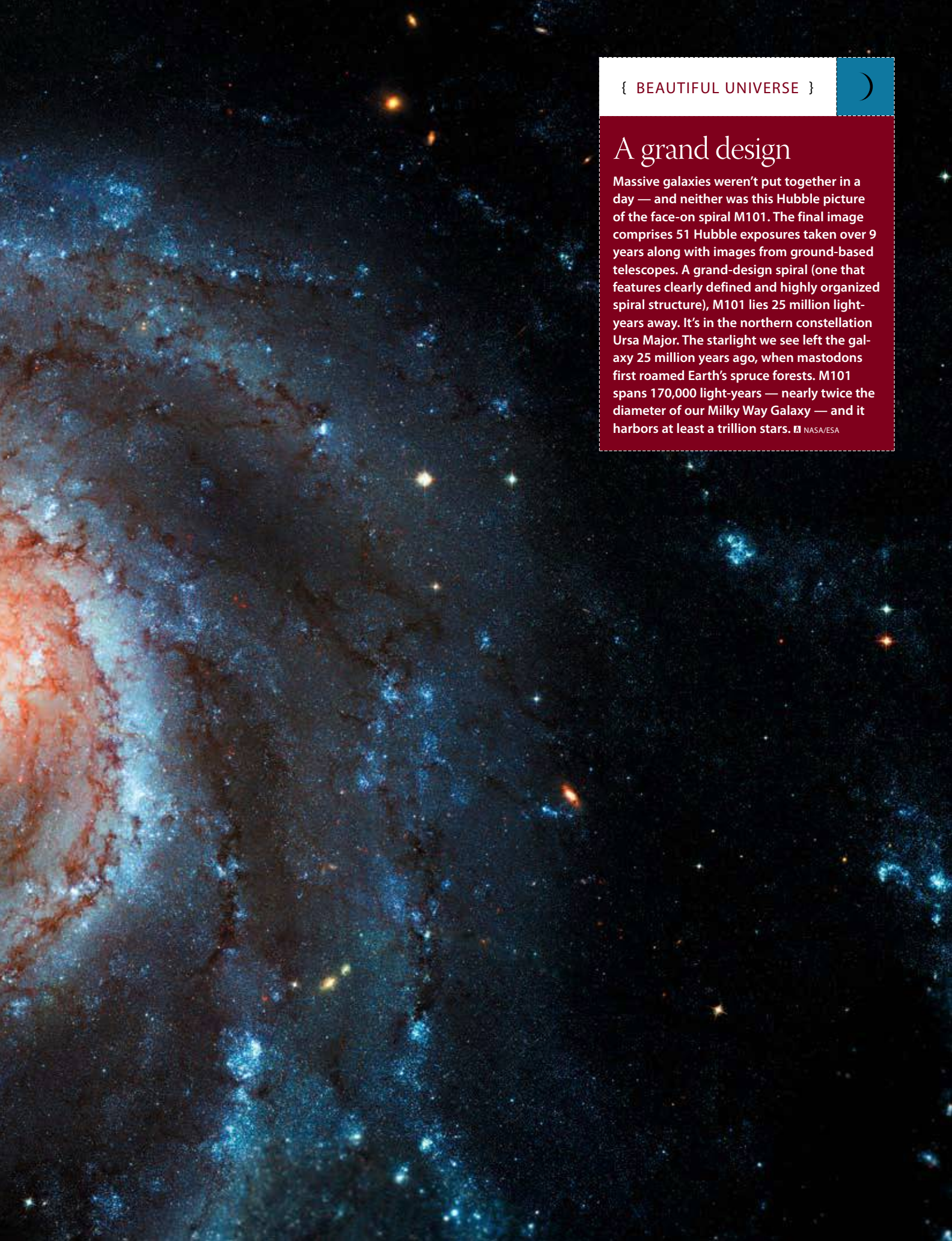

A grand design

Massive galaxies weren't put together in a day — and neither was this Hubble picture of the face-on spiral M101. The final image comprises 51 Hubble exposures taken over 9 years along with images from ground-based telescopes. A grand-design spiral (one that features clearly defined and highly organized spiral structure), M101 lies 25 million light-years away. It's in the northern constellation Ursa Major. The starlight we see left the galaxy 25 million years ago, when mastodons first roamed Earth's spruce forests. M101 spans 170,000 light-years — nearly twice the diameter of our Milky Way Galaxy — and it harbors at least a trillion stars. NASA/ESA

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Astro-Tech's new 111mm *ED triplet apo* is only $1895.

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The **Astro-Tech AT111EDT** is a 111mm f/7 ED *triplet* apo for only $1895. Its 4.4" aperture gathers 18% more light than a 102mm (4") scope. At 24" long, it's a superb scope for the traveler. The AT111EDT has a rotating dual-speed 2.7" rack and pinion focuser; 1.25" and 2" compression ring eyepiece holders; a hard case; and more.

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The low prices of these **Konus** telescopes are downright amazing.

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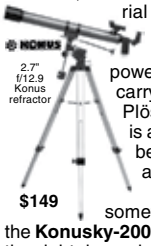

2.7" f/12.9 Konus refractor

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Or, if you want something a *lot* bigger, the **Konusky-200** 8" f/5 reflector, to the right, has a heavy duty equatorial mount with a steel leg tripod, *dual-axis* DC motor drives for astrophotography, *two* 1.25" Plössl eyepieces, an 8 x 50mm finderscope, star-charting software, and a polar axis finder. It's a lot of telescope for only $649!

8" f/5 Konus reflector

$649

The Konus **Motormax-150** 6" Maksutov-Cassegrain, above right, has the same heavy duty equatorial mount and useful accessories as the 8" reflector. It's a terrific value at its low price of only $799, which is well below the cost of other large Maksutovs.

6" f/12 Konus Maksutov

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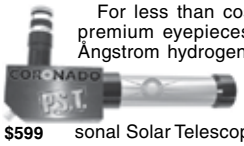

$599

For less than cost of some premium eyepieces, the sub-Ångstrom hydrogen alpha line filter in the **Coronado PST** (Personal Solar Telescope) lets you see the ever-changing drama of solar flares and prominences growing and subsiding before your eyes, not just the sunspots you see with an ordinary filter.

The PST gives you a 40mm refractor with a full-time built-in solar filter, a safe built-in Sun finder, and a 20x eyepiece.

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If you have only a casual interest in the skies, or just want a reasonably-priced gift for an astronomy newcomer, you'll love the easy setup and operation of a **Celestron AstroMaster**. These scopes have good optics and sturdy manual mounts that let you explore the skies on your own. Each has *two* eyepieces, a red dot finder, manual slow motion controls, steel tripod, computer software to print out sky maps for your observing sessions, and more.

The Celestron AstroMaster scopes are available in these sizes and types:

AM70A	70mm altazimuth refractor ..	**$129.95**
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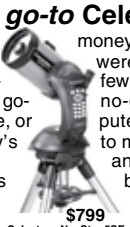
When we opened in 1979, a Celestron 8 cost $1295. Today, an even better *go-to* Celestron 8 is only $1399.



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5" Schmidt-Cassegrain

The best 1979 Celestron C8, which we sold back then for $1295, would cost $3667.08 in today's inflated dollars – but wouldn't have the go-to computer, multicoatings, DC drive, or quality Plössl eyepiece of today's $1399 **Celestron NexStar 8 SE.**

But it *would* still have Celestron's superb Schmidt-Cassegrain optics. That's one important benefit for you that hasn't changed over the years.

When you think about it, a Celestron's cost has actually *deflated* over the years. You get more scope, but you pay less money, because many of today's features were unavailable at *any* price only a few short years ago. Features like the no-guesswork *SkyAlign* go-to computer that finds objects automatically to make astronomy as easy as 1-2-3, and Starbright XLT multicoatings for brighter images and higher contrast.

Is a **Celestron NexStar SE** a great value? *Absolutely!*

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NexStar 8 SE,	8" Schmidt	**1399**

The hot Celestron SkyScout. In stock now.

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Last fall, it was almost impossible to find the **Celestron SkyScout**. This *Sky & Tel Hot Product for 2007* is still selling like there's no tomorrow, but we have a SkyScout in stock for you today.

This GPS-based non-magnifying handheld personal planetarium locates and identifies over 6,000 celestial objects visible to your unaided eye. Earbuds tell you their stories, or you can read them on a scrolling 5-line text and graphics display.

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GPS tells a Meade LX90 where it is . . . so you don't have to!

Meade 8" LX90-GPS
$1999

Meade LX90 8", 10", and 12" go-to Schmidt-Cassegrain telescopes use a GPS (Global Positioning System) that makes it easy for you to find your way to any object in the night sky. The high light transmission of their UHTC multicoated optics makes sure you see everything there is to see once you get there.

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Simply check that your LX90's finderscope (it has two, an 8 x 50mm and a red dot) is centered on those stars, then start enjoying the best in 21st century computerized go-to observing at the touch of a button. A Meade LX90 makes astronomy pushbutton easy.

Here are the prices on the Meade LX90 scopes that we stock:

8" LX90-GPS,	UHTC optics	**$1999**
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TMB triplet apo refractors start under $1000!

TMB 80
triplet apo
$995

The **TMB Optical TMB-80** 80mm f/6.3 triplet apo refractor is only $995. It's the first time a genuine TMB Optical refractor has been available at such an attractive price. Like all TMB refractors, it uses premium FPL-53 ED glass in a fully multicoated apochromatic (color-free) triplet lens. The TMB-80 has a rotating 2" Crayford focuser, 1.25" and 2" compression ring eyepiece holders, and more. A TMB apo for under $1000? Wow!

TMB-130
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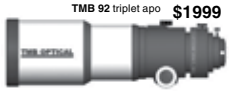
The 130mm f/7 **TMB-130** apochromatic triplet, left, is a *Sky & Telescope Hot Product for 2007.* Unlike other premium refractors that have multiyear waiting lists, this outstanding $3999 apochromatic refractor from renowned optics designer Thomas M. Back is available now.



TMB 92 triplet apo **$1999**

The very compact 92mm f/5.5 **TMB-92** triplet apo to the right fills the void left by the discontinued 90mm Astro-Physics Stowaway (a legendary scope that sells for up to $6000 on the used market). But you won't pay $6000 for the TMB-92. This fast focal ratio 92mm TMB apo is only $1999.

The TMB-130 and TMB-92 both have collimatable lens cells and each features a famous *FeatherTouch* dual-speed rotating rack and pinion focuser (a 3.5" drawtube model on the TMB-130, and a 2.7" on the TMB-92).

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BY BOB BERMAN

No green stars for Johnny

What did we do with all our free time

the past 200,000 years? By day, we mostly stared at the furry clothes we'd tossed on the cave floor and thought about cleaning them up someday. At night, we watched the stars. We noticed only two of their properties: brightness and color. Brightness differences were obvious, and the color business should have been just as clear cut. It wasn't, and still isn't.

Here's the scoop. At wavelengths of 500 to 570 nanometers, right in the middle of the solar spectrum, our eyes see the color green. This is where our Sun emits energy most strongly, so green looks prominent when sunlight is projected by a prism. Human visual sensitivity peaks in the yellow-green in bright conditions and blue-green when light is dim, further enhancing the Sun's brilliance. Any way you slice it, green stands out.

But look: The Sun emits plenty of red and blue, too. When these three primary colors hit our eyes together, we perceive the mixture as white.

So, the Sun is seen as a white star. It's not a green star. If our Sun doesn't look green even though it peaks at green, you can be sure no other stars can look green either. There are no green stars for several reasons. First, no star exists that emits only green light. Second, you can only get green from green, not from any combination of other hues, because green is a primary color. (Remember, we're talking about light, not paint.) Third: No stars have their reds and blues both suppressed at the same time so that green can strongly dominate.

Cool stars emit some blue, more green, and lots of red, a combination that yields pastel orange: Look at Antares. Very hot stars emit an excess of blue, but still give off lots of red and green. Try it on your computer's paint program. Mix 250 parts of blue, 215 parts of green, and 195 parts of red, and see what you get. It'll closely match the appearance of Rigel or Spica.

As for yellow stars, well, yellow is what our eyes see when green and red light are equally present but blue is weak or absent.

IF OUR SUN

doesn't look green even though it peaks at green, you can be sure no other stars can look green either.

So, a yellow star automatically tells you that its blues are subdued, meaning it's not terribly hot. And no, our Sun is not a yellow star. It's listed that way in some texts, but astronauts and high-altitude balloonists report the Sun to be as white as snow.

The reason the Sun looks lemony from Earth's surface is that some of its blue light gets scattered by our atmosphere. The blue sky didn't come from nowhere. All that blue was robbed or subtracted from incoming sunlight, which left it with an excess of red and green. This combo, as we've seen, yields yellow. The blue sky and the yellow Sun go together. We wouldn't have one without the other.

You can easily put those colors back together. When no one's watching, stand outside examining a blank sheet of paper on a cloudless day. Sunlight bounces off the paper, and so does blue light from the sky. The two re-combine, producing the true color of the Sun as seen from space. Your friends may not feel the same excitement when staring at a blank page.

Star colors are almost always pastels, like the hues most people use for interior housepaint. Suns never have saturated colors, like a stop sign's red. That's because the blue, red, and green in their spectra automatically combine into white, which dilutes any dominant color. But a few extremely cool stars, in both the temperature and the hip sense, have such weak blues and skimpy greens that only a little white can form, which results in a purer, deeper orange-red. Check out R Leporis, Mu Cephei, or Y Canum Venaticorum. They look like glowing coals.

A fun toy for us astro-geeks is a good quality handheld spectroscope, or else a "star spectroscope" to examine stellar spectra through a telescope. The results are gorgeous and fascinating, and they reveal what wavelengths any star emits.

It's also fun to inspect a true-color wide-field Milky Way image. Go to Google Image Search to locate a large version. Examine a few hundred stars. You'll see suns that are white, yellow, orange, and blue-white — but not green.

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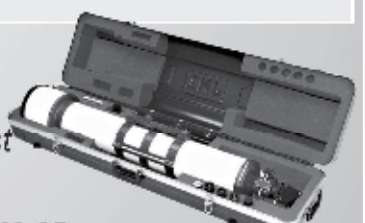

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BY STEPHEN JAMES O'MEARA

The secret Lagoon

On July nights, the Milky Way's oval

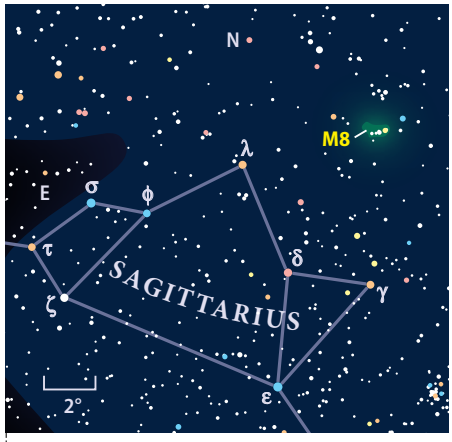
hub dominates the south celestial landscape. Most magnificent is the flood of starlight between the tip of the Scorpion's tail and Sobieski's Shield (Scutum). If you sweep your eyes along this milky trail, you'll find that it swells in brilliance near the spout of the famous Teapot asterism in Sagittarius. Here, dense pools of stellar mist mingle with dark veins of dust toward the galactic center.

But if you look just above this milky core, about 5° west and slightly north of 3rd-magnitude Lambda (λ) Sagittarii — the star marking the Teapot's tip — you'll see a solitary sprig of diffuse light that burns like a distant lantern emerging from a fog. This is the renowned Lagoon Nebula (M8), which has a fascinating and somewhat mysterious history.

M8 is a bright ornament in the naked-eye Milky Way and was likely seen by many ancient skywatchers in their casual scans of the heavens. But the Italian astronomer Giovanni Batista Hodierna (1597–1660) first drew attention to the glow in his 1654 catalog, *De Admirandis Coeli Caracteribus*.

But Hodierna does not classify it as a nebula. He places it in a category of objects that appear nebulous to the unaided eye but resolve into stars with a simple 20x Galilean refractor.

When English astronomer John Flamsteed (1646–1719) independently discovered M8 around 1680, he described it simply as a "nebula." But here's a curious historical twist: In his classic 1975 book, *The Search for the Nebulae*, the late Kenneth Glyn Jones credits Flamsteed not with the discovery of M8's nebulosity, but with NGC 6530 — its associated open star cluster. As a side note, Brent Archinal and Steven Hynes, in their wonderful 2003 book *Star Clusters*, argue M8's star cluster has been incorrectly labeled NGC 6530 since the mid-19th century and should also be identified as NGC 6523.



SAGITTARIUS' well-known asterism the Teapot serves as a signpost for locating M8. Simply follow the steam rising from the pot's spout. *ASTRONOMY*: ROEN KELLY

It's uncertain as to why Jones made the change, although he does note that many of the 16 objects listed as nebulae or nebulous stars in Flamsteed's star catalog *Historia Coelestis Britannica* were later found to be asterisms. Indeed, M8's cluster does lie about 20' east-southeast of 5th-magnitude 7 Sagittarii, and the two objects do blur together with a glance. Is there evidence that this blurring effect is what Flamsteed observed?

Perhaps. No nebula is plotted at M8's position on the *Atlas Coelestis*, the 1729 star atlas that supplements Flamsteed's star catalog. What is plotted are the stars 7 Sagittarii and 6th-magnitude 9 Sagittarii — the brightest member of M8's open cluster. Then again, no nebulae appear on that star atlas, not even the Andromeda "Nebula" (M31), known since antiquity.

When French astronomer Philippe Loys de Chéseaux (1718–1751) reviewed Flamsteed's "nebula" sometime between 1745 and 1746, he, like Hodierna, concluded that it appears as a "truly nebulous" star when seen "by sight alone" but as a simple star cluster when seen through a telescope.

Now brace yourself for a bump. In his famous catalog of clusters and nebulae, French astronomer Charles Messier (1730–1817) makes a fascinating, and perhaps revealing, comment about M8, May 23, 1764: "A cluster of stars that appears to be a nebula when observed with a simple three-foot refractor; with an excellent instrument, however, one sees only a large number of faint stars. Near this cluster there is a fairly bright star [9 Sagittarii], which is surrounded by a very faint glow."

Mind over matter?

"First there is a mountain, then there is no mountain, then there is." — "There is a Mountain" by Donovan

The observations mentioned above would not be surprising if it weren't for the fact that both the nebula and the cluster are visible to the naked eye under a dark sky. Respected New Mexico visual observer Becky Ramotowski notes that although she can see the stars in and around M8, "The nebulosity stood out on its own as a noticeable feature first. The nebula looks like a melted marshmallow that has dropped off a hot skewer and plopped on the ground."

One theory explaining the early observations concerns the mind's power over the eye. After Galileo resolved the Milky Way into stars through his telescope, some 17th- and 18th-century observers, like Hodierna, adopted the belief that all nebulae were simply clusters of stars that telescopes could resolve, given sufficient

THE LAGOON NEBULA appears divided by a lane of obscuring dust. Although easily identified in this processed image, spying the dust "lagoon" through binoculars is a challenge accomplished only with a dark sky, steady hands, and good eyes. TONY AND DAPHNE HALLAS

aperture. Couple this belief with the imperfect views given by these simple telescopes, which not only had crude optics but narrow fields of view, and you have a formula for vanishing nebulae. In other words, if you magnify a delicately diffuse and large (90') glow surrounding a bright star cluster through an inferior telescope, the nebula will vanish from view as the cluster flares to prominence. Just as a magician's veil can become a bouquet of flowers — *Voilà!* — M8's veil of nebulosity can become a bouquet of stars.

The question is: How many of these early telescopic observers unconsciously refused to see any vestige of nebulosity under the power of belief? We may never know the answer. No matter, we at least know one fact: Messier saw a "very faint glow" around 9 Sagittarii that obviously didn't resolve into stars through a scope of "excellent quality." And this is where the brightest concentration of nebulosity in the Lagoon Nebula lies.

Save the best for last

Two outstanding telescopic observations of M8's nebulosity prior to Messier's do exist. In 1747, French astronomer Guillaume Le Gentil (1725–1792) used an 18- to 20-foot-focal-length telescope to discover "a small nebulosity like the tail of a comet with numerous stars" in Sagittarius.

Although Le Gentil's position for the object is in error by more than 1°, it's clear from the position, and his more detailed description, that the object the French astronomer discovered is M8.

The other observation belongs to the southern explorer Abbè Nicolas Louis de Lacaille (1713–1762), who used a 1/2-inch 8x telescope to discover this object, which appeared to him as "3 stars enclosed in a trailing nebulosity." He included it in his 1755 catalog of deep-sky objects under the heading "stars accompanied by nebulosity."

Now, I'm interested in what you see. Can you separate M8's nebulosity from its cluster? E-mail me at someara@interpac.net.

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ALMA link On March 2, scientists linked two prototype antennae of the Atacama Large Millimeter Array to view Saturn — the array's first astronomical observation.

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HABITABLE ZONE. A 5-Earth-mass planet circles the red-dwarf star Gliese 581 in this artist's impression. This is the first known exoplanet where liquid water could exist on the surface. EUROPEAN SOUTHERN OBSERVATORY

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Super-Earth found in habitable zone

Astronomers say Gliese 581 — a red-dwarf star located 20.5 light-years from Earth in the constellation Libra — harbors the most earthlike planet yet discovered. This super-Earth packs at least 5 times Earth's mass into a sphere about 1.5 times Earth's radius. But most intriguingly, the planet lies in Gliese 581's habitable zone — the region around the star where liquid water could exist.

The newly discovered planet is the smallest-known exoplanet in orbit around a normal star. It circles Gliese 581 every 12.9 days at a distance of 6.8 million miles (10.9 million kilometers). Although that's only 1/14 Earth's distance from the Sun, Gliese 581 radiates just 1 to 2 percent of the Sun's energy.

Barring a greenhouse effect, the planet's proximity should keep its surface between about 32° and 104° Fahrenheit (0° to 40° Celsius), just right for liquid water. Whether water exists there is another matter. At this mass, the new planet could be rocky or mostly gaseous.

The new super-Earth joins at least two other planets known around Gliese 581: a 15 Earth-mass planet that circles the star in 5.4 days, and an 8 Earth-mass planet that orbits in 84 days.

Stéphane Udry of the Geneva Observatory led the team that discovered the new planet. The scientists have submitted their results as a Letter to the Editor in *Astronomy and Astrophysics*. — **LAURA LAYTON**

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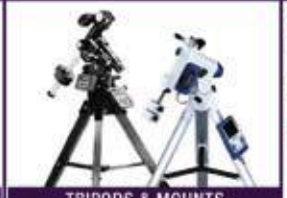
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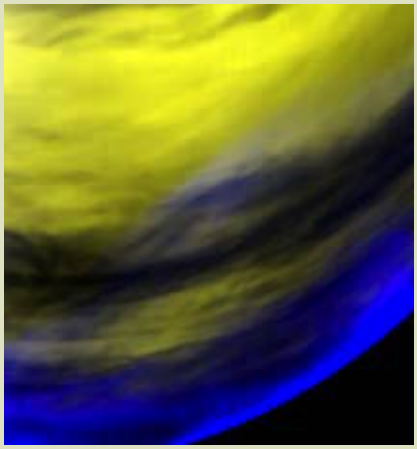
Venus' space-lantern glow

Infrared images taken by the European Space Agency's Venus Express spacecraft are giving astronomers an unprecedented look at the "space-lantern" glow of oxygen molecules in the planet's turbulent, poisonous atmosphere.

The eerie glow, visible only on Venus' night side, starts when ultraviolet photons from the Sun smash into carbon-dioxide molecules, which make up 97 percent of the planet's atmosphere.

This liberates oxygen atoms, which drift to the night side on high-altitude winds. There, they migrate to the lower-altitude mesosphere (or middle layer, at an altitude between 37 and 68 miles [60 and 110 kilometers]), where they recombine to form molecular oxygen. This recombination gives off infrared light at a wavelength of 1.27 micrometers.



ESA/VIRTIS/INAF-IASF/OBS. DE PARIS-LESIA

LIGHT AT NIGHT. This false-color image snapped by Venus Express reveals the planet's nighttime oxygen airglow. The blue color corresponds to infrared light emitted when oxygen atoms recombine in the atmosphere's mesosphere.

The airglow is beautiful, but it also helps researchers studying Venus' atmospheric dynamics. For example, scientists can harness the airglow to trace motions in the mesosphere. — **DANIEL PENDICK**

25 years ago in *Astronomy*

August 1982

"Backtracking the comets" gave readers a history of attempts to learn where comets come from. It should be easy to backtrack these celestial misfits using Newton's laws of motion, argued then-freelance science writer Francis Reddy (now an *Astronomy* editor). However, claimed Reddy, "We have backtracked the comets in both space and time, yet we have found no certain solution to the mystery of their origin."

Despite progress, astronomers still argue the origin of comets, including that of 2007's Great Comet, McNaught, which appeared early this year. Comets remain, 25 years later, "spectacular to the eye, intriguing to the mind, but far from being understood."

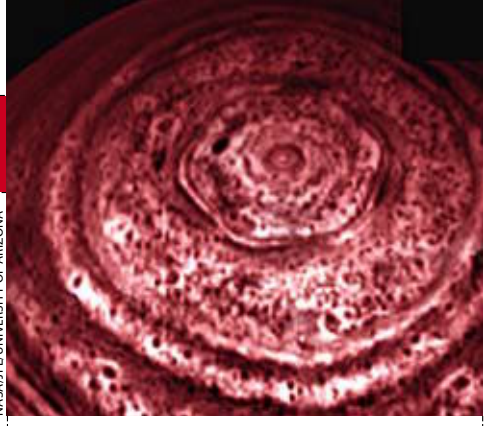
10 years ago in *Astronomy*

August 1997

August 1997 saw most of the world still reeling from the 1996 discovery of a possible fossilized microbe in a martian meteorite. "The new martian chronicles" detailed the hurdles of sending a manned mission to Mars, from flight costs to astronauts' health risks.

Science writer David S. F. Portree argued that a manned operation was of utmost importance and that, "Humans could do the same science on Mars in one or two years that robots could do in 100 or 200 years." However, he argued, "There's no way to predict when the lightning of political support will strike life into a program."

Portree said NASA engineers were setting their sights on the year 2011, claiming that we might see a "martian outpost" by that time. We'll have to wait a bit longer: In 2004, President Bush proposed a manned trip to Mars that was expected to be at least 10 years in the making, and Europe's Aurora mission doesn't plan to send humans to Mars until 2030. — **KATIE NEUBAUER**



NASA/JPL/UNIVERSITY OF ARIZONA

POLAR HEXAGON. **This six-sided feature around Saturn's north pole spans 15,000 miles (25,000 km) and extends 60 miles deep (100 km).**

Six sides of Saturn storm

NASA's Cassini spacecraft has imaged a strange, six-sided feature that wraps around Saturn's north pole. The hexagon apparently has a long life — the Voyager 1 spacecraft first imaged it 26 years ago.

The image, taken with Cassini's Visual and Infrared Mapping Spectrometer (VIMS), records the feature's infrared glow. It shows the hexagon extends some 60 miles (100 kilometers) below Saturn's cloud tops, much deeper than scientists expected. It spans nearly 15,000 miles (25,000 km).

"We've never seen anything like this on any other planet," says Kevin Baines of NASA's Jet Propulsion Laboratory, a VIMS team member. It looks strikingly different from what scientists see at Saturn's south pole: a hurricane-like vortex with a giant eye. — **RICHARD TALCOTT**

BRIEFCASE

Magnetic cloud

Radio astronomers have discovered a plasma cloud spanning 6 million light-years near the Coma cluster of galaxies. Team leader Philipp Kronberg of Los Alamos National Laboratory suggests black holes in galaxies embedded in the cloud may be its source. — **L. L.**

MGS' demise

A NASA review board concluded Mars Global Surveyor (MGS) succumbed to battery failure. On November 2, alarms caused MGS to reorient itself. In so doing, it exposed one battery to direct sunlight, causing it to overheat and ultimately deplete both batteries. — **R. T.**

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Bullets in Orion

Using the 8-meter Gemini North Telescope on Mauna Kea, astronomers have resolved gaseous "bullets" piercing clouds of molecular hydrogen in the Orion Nebula (M42). The image's exceptional resolution comes from a new adaptive-optics system that uses a laser guide star and a rapidly deformable mirror to compensate for distortions in Earth's atmosphere.

These bullets were discovered in 1983, but this is the first time their structure has been seen in detail and their trailing wakes imaged as filaments. Astronomers believe events deep within the nebula ejected the bullets less than 1,000 years ago. They're now speeding outward at up to 900,000 mph (1.5 million km/h).

As the bullets slam into the surrounding cloud, the collisions destroy the hydrogen molecules that make up the bulk of both the bullets and cloud. Iron atoms at the tip of each bullet then glow brightly (blue in this near-infrared image) as friction heats them to about 9,000° Fahrenheit (5,000° Celsius). The hydrogen molecules on the bullets' trailing edges are not destroyed, however. These tubular wakes (orange in the image) glow as friction heats them to around 4,000° F (2,000° C). — **R. T.**

GEMINI OBSERVATORY

TUBULAR WAKES. "Bullets" of hydrogen molecules stream at hypersonic speed from the heart of the Orion Nebula. This adaptive-optics, near-infrared image shows structures as small as 0.1" across.

In the danger zone

A super-hot O-type star more than likely would destroy any developing protoplanetary disks surrounding nearby, cooler stars. The danger zone extends about 1.6 light-years from the O star's fiery surface.

Astronomers used NASA's Spitzer Space Telescope to survey infrared-bright disks around 1,000 stars in the Rosette Nebula (NGC 2237–9), which lies 5,200 light-years from Earth in the constellation Monoceros. The researchers, led by Zoltan Baloy of the University of Arizona, mapped out these hot stars' danger zones.

They found that 1.6 light-years or farther from an O-type star, about 45 percent of stars had disks — the same amount as in safer, O-star-free neighborhoods. Inside 1.6 light-years, only 27 percent of stars had disks. The percentage dropped the closer those stars were to an O star.

The disks wither under the onslaught of ultraviolet radiation, which heats and evaporates a disk's gas and dust; then, the O star's strong wind blows the material away. The astronomers reported their results in the May 20 issue of *The Astrophysical Journal*. — **L. L.**

NASA/JPL-CALTECH/Z. BALOY (UNIV. OF ARIZONA)

DANGER, WILL ROBINSON. This Spitzer image of the Rosette Nebula shows five super-hot O stars. Strong winds and intense radiation create danger zones (shown as bluish spheres) around these stars, where planets likely can't form.

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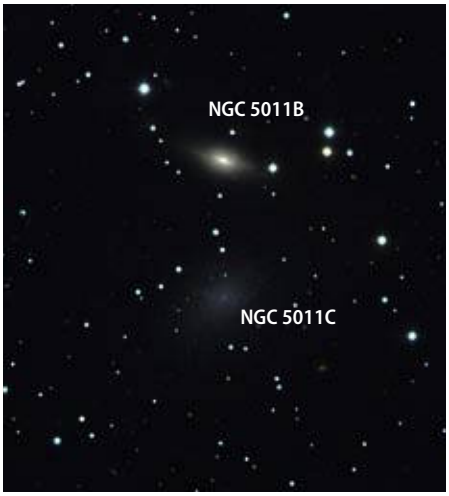


ESO

NOT NEIGHBORS. **NGC 5011B and NGC 5011C look like a pair, but the former lies nearly 150 million light-years beyond.**

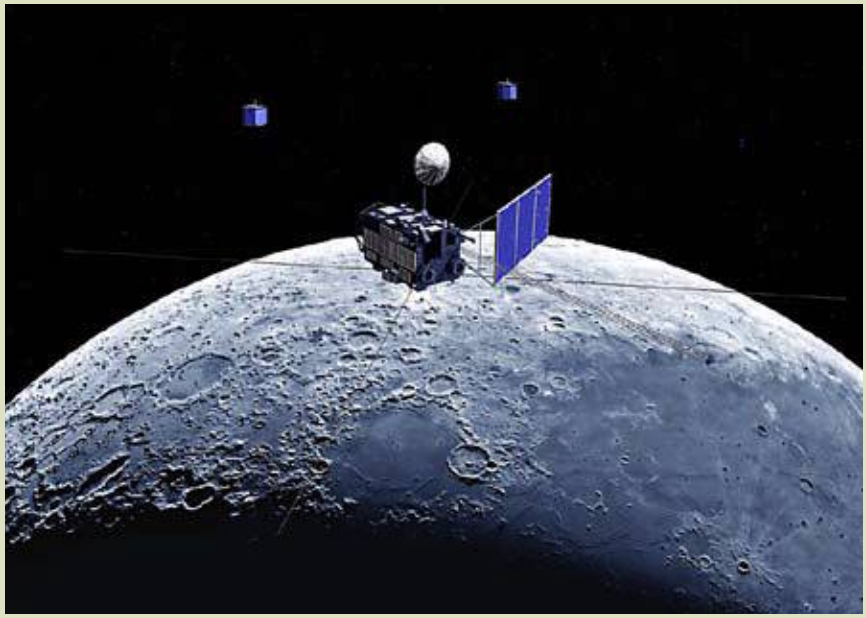
A pair no longer

Since the mid-1980s, astronomers have thought that two neighboring galaxies in the constellation Centaurus were related. Even their designations imply kinship: NGC 5011B and NGC 5011C. Now, researchers have found the two lie more than 100 million light-years apart.

The brighter and redder object, NGC 5011B, lies in the Centaurus cluster of galaxies some 150 million light-years from Earth. If NGC 5011C were as far away, it would be bigger than its neighbor but with a much lower surface brightness — a type of galaxy never seen before. Plus, despite their proximity on the sky, the two show no signs of interaction.

Ivo Saviane of the European Southern Observatory (ESO) and Helmut Jerjen of Mount Stromlo Observatory in Australia used the 3.6-meter ESO telescope in Chile to examine both galaxies. From the galaxies' redshifts, the astronomers found NGC 5011C lies 13 million light-years from Earth, placing it in the Centaurus A galaxy group. That makes it a fairly typical dwarf elliptical galaxy, containing about 10 million stars.

The spectral observations also show NGC 5011B possesses more heavy elements than 5011C. Saviane and Jerjen report their findings in the April issue of *The Astronomical Journal.* — **R. T.**



JAXA

TO THE MOON. **Japan is scheduled to launch its lunar probe Selene in August. It will map the Moon's composition, geography, and gravity field.**

Japan on the move

With lunar probes from China and India in their final months of launch preparations, a third Asian contender has reappeared suddenly after being widely considered out of the race. Japan's Selene orbiter is now scheduled for launch aboard a powerful H-2A booster from the Tanegashima Space Center in August, just ahead of the Chinese Chang'e mission.

In a previous incarnation, Selene was to carry impactor probes designed to survive high-speed landings on the Moon's farside. Careful testing convinced Japanese space scientists the design would not work, so the probes were removed from the "mother ship" — and offered free to any other spacefaring nation that wanted to tinker further with them.

In place of the impactors, Selene will now carry two subsatellites. They will act as communication relays between the main probe and Earth during portions of each orbit when the probe flies behind the Moon. Live retransmission will let scientists detect real-time trajectory wobbles, allowing them to map mass concentrations ("mascons") below the surface.

The 3-ton Selene and its suite of 14 scientific instruments cost the Japanese space agency (JAXA) approximately 55 billion yen (some $450 million U.S.). Although financial arrangements had not been worked out for operating the launch site as a government-commercial partnership, that was merely a familiar terrestrial budget battle.

Selene will orbit the Moon at an altitude of 60 miles (100 kilometers) and send data back for at least a year. This guarantees overlap with the operations of both the Chinese and Indian probes. Selene will observe the lunar surface and remotely probe beneath it.

JAXA says its mission is to collect information on "the formation of the Moon and its transitional history up to today," tackling questions scientists had not been smart enough even to ask prior to the Apollo landings. "Moon science is full of unknown territory," says Shinichi Sobue, head of the Selene project development team.

Besides mapping the distribution of elements and geographical formations, Selene will study the Moon's gravitational field to examine in detail underground structures and the distribution of iron and other potentially valuable, heavy metals. Japanese officials say that while the mission has immense scientific value, mapping resources for future exploitation also is a project goal. — **JAMES OBERG**

Alien plants

If plants exist on an exoplanet, computer models say they could be green, yellow, or red, depending on the host star's color and the planet's atmospheric content.

Could black holes seed life?

An international team of astronomers says black holes may spread the chemical building blocks of life throughout the cosmos. The team, led by Yair Krongold of the Universidad Nacional Autonoma de Mexico, found gas escaping from just beyond the event horizon of a supermassive black hole at the heart of galaxy NGC 4051.

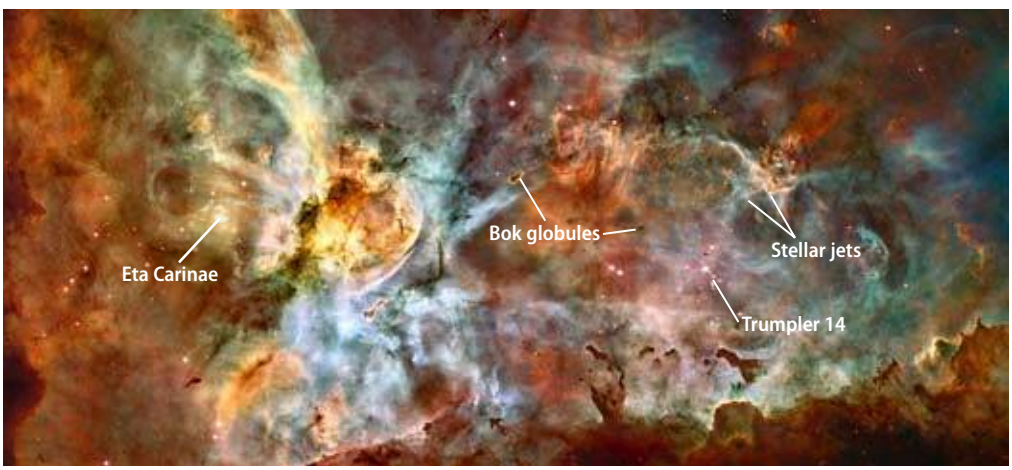
A black hole's environs produce hot winds gusting at speeds up to 4 million mph (6.5 million km/h), which could carry carbon and oxygen atoms vast distances.

"We calculate that between 2 and 5 percent of the accreting material is flowing back out," says team member Fibrizio Nicastro of the Harvard-Smithsonian Center for Astrophysics. The rest gets swallowed by the black hole.

GEORGE SEITZ/ADAM BLOCK/NOAO/AURA/NSF

HOT WIND. The supermassive black hole hidden at the center of this spiral galaxy, NGC 4051, emits large amounts of carbon and oxygen.

The scientists observed the escaping gas with the European Space Agency's XMM-Newton satellite. They reported their results in the April 20 issue of *The Astrophysical Journal*. — **L. L.**



NASA/ESA/N. SMITH (UC, BERKELEY)/THE HUBBLE HERITAGE TEAM (STScI/AURA)

FLASHY NEBULA. The Eta Carinae Nebula resolves into a fantasyland in this Hubble mosaic. You can easily pick out Eta Carinae, the nebula's brightest star, several dark Bok globules (where new stars are forming), jets from newborn stars, and the 2.5-million-year-old star cluster Trumpler 14.

Massive star factory unveiled

The Hubble Space Telescope has laid bare the Eta Carinae Nebula (NGC 3372), the sky's brightest emission nebula. The image — comprising 48 frames from Hubble's Advanced Camera for Surveys — shows star birth in unprecedented detail.

This 50-light-year-wide view captures just part of the nebula. More than a dozen brilliant stars, each at least 50 times the Sun's mass, dot the nebula. At the top of the list is Eta Carinae itself: a 100-solar-mass giant that ranks among the most luminous and violent stars known (see "The supernova next door," June 2007).

Fierce stellar winds and energetic ultraviolet radiation emanate from these hot, massive stars and sculpt the surrounding gas and dust into fantastic shapes. The myriad dark tendrils mark sites where new stars likely are forming.

The nebula began creating stars about 3 million years ago, when its first stars condensed out of a huge cloud of cold molecular hydrogen. Radiation from those stars ionizes much of the surrounding gas and causes it to glow. Meanwhile, stellar winds compress some of the remaining cold gas, triggering new waves of star formation. — **R. T.**

QUICK TAKES

BIG BALLOON
Astronomers have discovered the lowest-mass white dwarf known: a Saturn-sized helium ball containing about one-fifth of the Sun's mass.

GET LOST
A December 6 solar flare triggered a powerful solar radio burst, which caused many earthbound receivers to stop tracking the Global Positioning System signal.

H_2O ON HD 209458B
Scientists have found water vapor in the atmosphere of HD 209458b, a gas giant with 70 percent of Jupiter's mass.

CLOAKING DEVICE
Physicists have constructed a material that bends visible light in the opposite direction from normal. This could lead to devices that render objects invisible.

SOLAR TWIN'S CYCLE
18 Scorpii, a near clone of the Sun in mass, temperature, and composition, also changes brightness like the Sun during its activity cycle.

LBT MILESTONE
February 21 saw the Large Binocular Telescope's first science result, when it captured a gamma-ray burst's 26th-magnitude afterglow.

WEAKEST LINK
Two stars, each weighing less than 100 Jupiters, orbit at 5,000 times the Earth-Sun distance — three times the old record for low-mass stars.

WHIRLPOOL OF DEATH
Observations of planetary nebula Sharpless 2-188 show dying stars leave whirlpools in their wakes as they plow through interstellar clouds.

GOING ONCE ...
London's Bonhams auction house accepted a bid of £138,000 ($272,000) for a rare, 14th-century astrolabe.

WAVES FOR THE CAMERA
The European Gravitational Observatory near Pisa, Italy, is teaming up with the U.S. LIGO to search for gravitational waves.

JUPITER up close and personal

The New Horizons spacecraft viewed giant storms, erupting volcanoes, ring clumps, and ionized particles as it flew past Jupiter on its way to Pluto. /// **BY S. ALAN STERN**

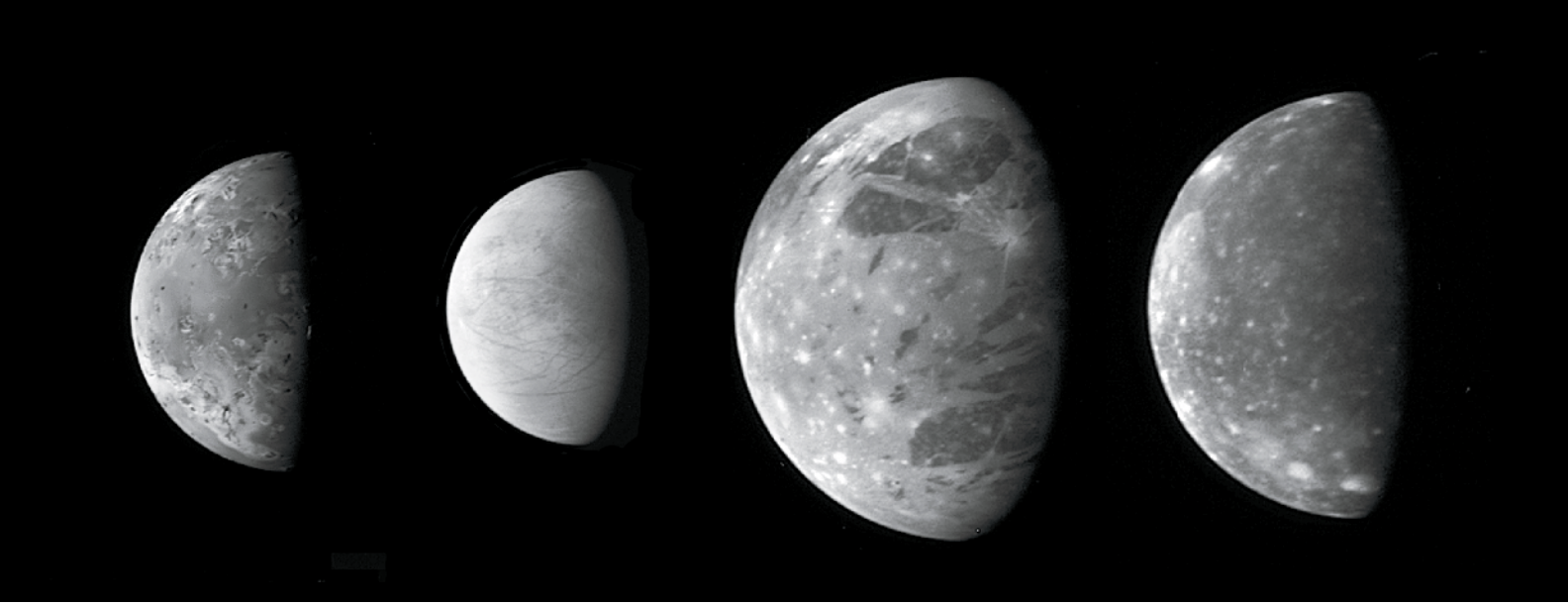
◀ HIGH CLOUDS stand out in this colorized image of Jupiter taken through a near-infrared methane filter. Dark spots in the southern hemisphere mark cloud-free regions. Violent thunderstorms appear as bright white spots. All images: NASA/JHUAPL/SwRI

From January to June, NASA's New Horizons spacecraft, on a fast track to Pluto, probed Jupiter and its surroundings with seven miniaturized scientific instruments. The craft conducted more than 700 separate observations of Jupiter and its aurorae, rings, moons, and magnetosphere.

This complex observing schedule gave New Horizons and its ground team a real-world workout that proved them capable of achieving a similarly complex set of activities when it makes the first-ever reconnaissance of Pluto, in 2015. And just as important, Jupiter's gravity acted like a slingshot, providing New Horizons with a 9,000 mph (15,000 km/h) speed boost.

New Horizons launched January 19, 2006, on a trajectory toward Pluto that incorporated a Jupiter gravity assist. Its

▲ A VOLCANIC PLUME erupts from Tvashtar (at the 11-o'clock position), near Io's north pole. The plume arcs 180 miles (290 km) above the surface. The smaller plume (20 percent as high) at 9 o'clock comes from another volcano — Prometheus.



THE GALILEAN MOONS posed individually in late February for this New Horizons' composite. Although the spacecraft never got real close to any of the moons, surface features on Io, Europa, Ganymede, and Callisto (left to right) still stand out.

13-month crossing from Earth to Jupiter set a record for reaching the gas-giant planet. Compare it with the previous Earth-to-Jupiter crossing, made by the Cassini spacecraft now orbiting Saturn, which took 3 times longer.

New Horizons approached no closer than 1.4 million miles (2.3 million kilometers) to the giant planet. The spacecraft's distance and position relative to Jupiter correspond to the "window" in space we had to fly though to slingshot onward to Pluto.

As luck would have it, this window and the timing of our February 28 closest approach conspired to put all four of Jupiter's planet-sized Galilean moons relatively far from New Horizons at closest approach. Nonetheless, we gathered some spectacular images and other observations of these four worlds. For more details on the flyby's logistics, see "New Horizons flies past Jupiter" in the April issue and the nine blogs I wrote for *Astronomy*'s web site (www.astronomy.com/newhorizons) during the encounter.

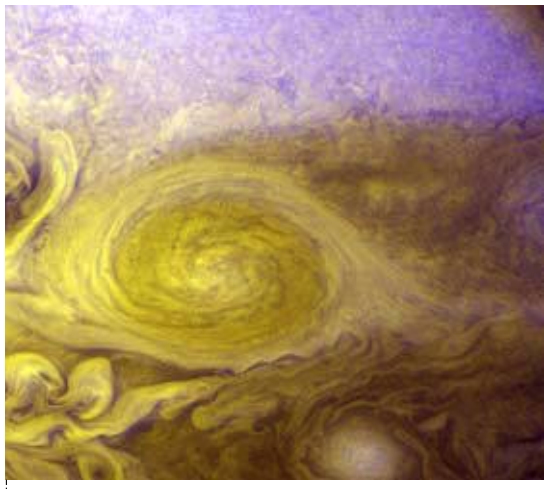
CRESCENT MOONS fill New Horizons' field of view. Volcanic Io (left) and Europa stood next to each other March 2, two days after the spacecraft's closest approach.

A first look at results

In every sense, the Jupiter flyby was a success. The only surprise we encountered with the spacecraft came from the Alice ultraviolet spectrometer, which shut itself down a couple of dozen times near closest approach. It couldn't completely handle the intense charged-particle radiation that surrounds Jupiter. The radiation did no damage to Alice, but we did lose about 5 percent of the science we expected to carry out during the flyby. (Fortunately, the charged-particle environment at Pluto will be far weaker.) Electronics in the other five instruments used at Jupiter were less sensitive to jovian radiation, and they made all of their planned observations.

All of the Jupiter-encounter data — a mother lode of more than 36 gigabits —has now been transmitted to Earth. Our science team is poring over the hundreds of observations we took, analyzing the data, and putting the archives in NASA's online Planetary Data System (pds.jpl.nasa.gov), where anyone can access them. Here, exclusively for *Astronomy* magazine, I am providing a sneak peek at some of the things we learned about Jupiter and its surroundings.

Jupiter's meteorology. New Horizons studied the dynamics of Jupiter's stormy atmosphere in fine detail — just 10 miles (16 km) per pixel — and revealed intricate three-dimensional cloud structures in stormy, turbulent regions. The chaotic

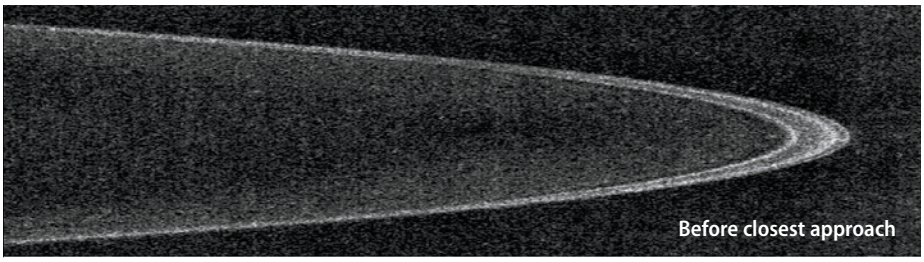


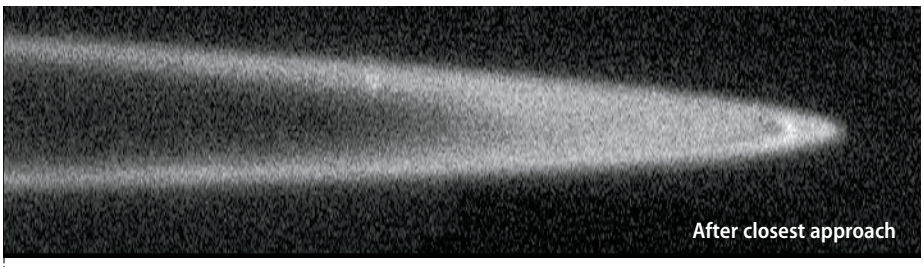
THE LITTLE RED SPOT doesn't look so small in this image, where it spans nearly half the field. The spot has a diameter 70 percent that of Earth, which makes it "little" only in comparison with the doubly large Great Red Spot.

nature of Jupiter's atmosphere appears in regions where air pushes upward, perhaps in a wavelike response to perturbations in the atmosphere's dominant east-west flow. This action triggers thunderstorms, which then release energy into the system.

In some less chaotic regions, New Horizons also observed vast wave trains of clouds stretching tens of thousands of miles across. These waves, whose crests align north-south, perpendicular to the wind's predominant east-west flow, indicate regions of Jupiter exist where stratified air layers are less prone to convection.

We focused much of our attention on the Great Red Spot and its smaller cousin, the recently formed Little Red Spot. New Horizons imaged the Little Red Spot in unprecedented detail and measured the





JUPITER'S CHARCOAL-BLACK RINGS contain particles ranging in size from boulders to fine dust. The top image — taken on approach — shows three ringlets. The bottom one, backlit by the Sun, reveals the fine dust that envelops the ring system.

spot's winds for the first time by comparing images made throughout the encounter.

Until a few years ago, the Little Red Spot was a more normal, white oval cloud feature. But in late 2005, its color changed to resemble that of its larger cousin, the Great Red Spot. We speculate this may be caused by an increase in the vertical transport of material from the depths of Jupiter to higher altitudes within the spot's core. Once the cloud particles reach high altitudes, we think the Sun's ultraviolet light photochemically changes them into the spot's reddish coloring.

Io's volcanism. New Horizons mapped the composition of all four Galilean satellites and probed the composition and structure of the tenuous exosphere surrounding each moon. The probe also searched for changes on volcanically active Io since the Galileo mission finished its work in 2003. We weren't disappointed.

The LORRI high-resolution imager snapped the best-ever photos of a large plume on Io. Time-lapse images of Tvashtar volcano are helping us directly measure particle speeds in a plume for the first time. In addition, New Horizons observed thermal emission from lava at the plume's source, giving us a handle on the lava's temperature. We also detected several surface changes on Io, including a new southern eruption near Lerna Regio (at longitude 290° west and latitude 55° south). This is the most significant surface change seen since 2001. Another new eruption appeared near 235° west and 20° north. This one seems to be the second-brightest hot spot on Io right now.

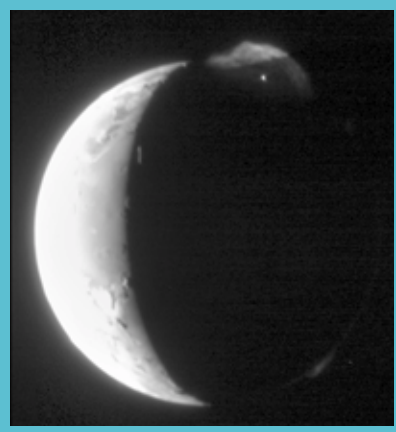
Newborn ring clumps. Jupiter's exceedingly faint ring system, discovered by the Voyager 1 spacecraft in 1979, consists almost exclusively of fine dust particles. Two tiny moons are embedded in the ring system: Adrastea (with a radius of 5 miles [8 km]) and Metis (with a radius of 12 miles [20 km]).

On approach to Jupiter, New Horizons obtained the clearest images ever of the ring system. They spanned two 8-hour "ring movies" designed to search for any additional embedded moons. Although we found no new moonlets, we discovered something much more interesting: a family of three closely spaced, bright clumps of ring material. Clumps in a ring should disperse rapidly — material closer to a planet orbits faster, so any loose clump will shear into a full ring within a year or so. That these three clumps exist at all implies they must be new. We estimate their ages at a few months or less.

How did they get there? Perhaps an impact into one of the ring boulders or undiscovered moonlets caused an explosion of dust, and we're seeing the remains of that blast. Such impact events must happen every now and then, but New Horizons was extraordinarily lucky to see the results of one so soon after it happened. No one has ever seen such an aftermath before.

Magnetotail exploration. After closest approach, New Horizons traveled down

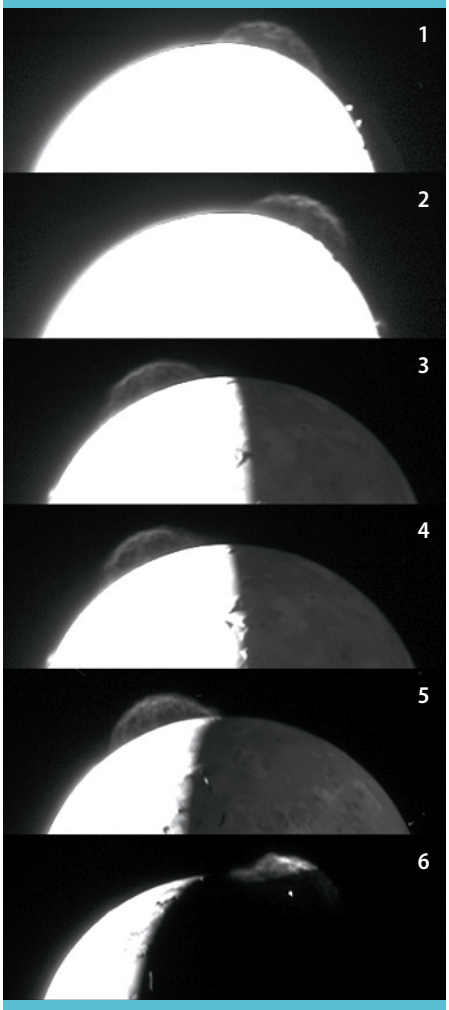
Io's volcanic hot spots



VOLCANICALLY ACTIVE IO looks different through different instruments. In visible light, detail appears on the sunlit crescent and on Tvashtar's partially lit plume. Hot lava at the plume's base shows as a bright spot.

LONGER WAVELENGTHS reveal Tvashtar's red lava, which contrasts nicely with its bluish plume. Sulfur and sulfur-dioxide deposits show up on Io's sunlit crescent.

AT INFRARED WAVELENGTHS, Tvashtar dominates, but at least 10 other volcanic hot spots show up on the moon's nightside.



TVASHTAR ERUPTS! **The six best images of Io's Tvashtar plume show its wispy structure evolves quickly. The six images span a bit over 2 days. In 5 years at Jupiter, the Galileo spacecraft never captured such detailed images of a large Io plume.**

SEVEN WAYS TO VIEW A PLANET

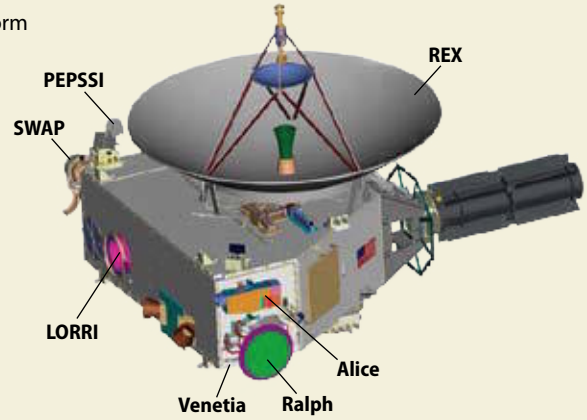
The seven instruments that form New Horizons' scientific payload were designed to address a wide range of first-time reconnaissance objectives in the Pluto system and in any subsequent Kuiper Belt objects we visit.

The payload has three remote-sensing instruments: Ralph, LORRI, and Alice. Ralph contains both a multicolor imager and a composition-mapping spectrometer.

LORRI — the Long Range Reconnaissance Imager — images in black and white with about 5 times higher resolution than Ralph, thanks to its longer focal length.

Alice is a sensitive ultraviolet imaging spectrometer designed for probing the composition and structure of planetary atmospheres and their aurorae.

New Horizons also carries three instruments that make in situ investigations of ionized plasmas and dust-particle concentrations the spacecraft flies through. The SWAP and PEPSSI space-plasma spectrometers measure the flux and composition of low-, medium-, and high-energy charged particles in space. SWAP and PEPSSI studied Jupiter's vast, teardrop-shaped magnetosphere as New Horizons flew through it from mid-February until June.



NEW HORIZONS' seven instruments range from cameras to a dust counter.
ASTRONOMY: ROEN KELLY

The Venetia Burney Student Dust Counter (Venetia for short) counts dust-particle impacts on the spacecraft and measures the mass of each impactor.

New Horizons also carries a radio science instrument called REX. At Jupiter, it was used only for self-calibration purposes. — *S. A. S.*

Jupiter's magnetotail for more than 200 million miles (320 million km) — more than 10 times farther than any previous exploration of a giant planet's magnetosphere. During this "magnetotail traverse," we explored the changing density and composition of the electrically charged plasma that fills Jupiter's magnetotail.

Our Pluto aim point fortuitously put the spacecraft on a course down the long axis of Jupiter's teardrop-shaped magnetotail. As a result, everything New Horizons saw in Jupiter's distant magnetotail was new: This was pure exploration! In fact, our SWAP and PEPSSI space-plasma spectrometers ultimately observed the magnetotail to a distance of more than 90 million miles (140 million km) — much farther than we originally had hoped.

Throughout the traverse, we observed low-energy ions, which varied in both intensity and peak energy. We also continuously observed oxygen and sulfur ions, even deep in the tail; they originate as molecules escaping from Io. We weren't surprised by these observations. The team was surprised, however, that the tail appears highly structured, with both gradual variations in plasma concentrations and several sharp boundaries between plasma regimes in the tail.

We also observed a number of strong particle bursts as we flew along, with the strongest having an intensity roughly 1,000 times that of the surrounding plasma. Amazingly, this occurred far down the tail, approximately 60 million miles (100 million km) beyond Jupiter. We still haven't figured out why such a burst occurred so far from the planet.

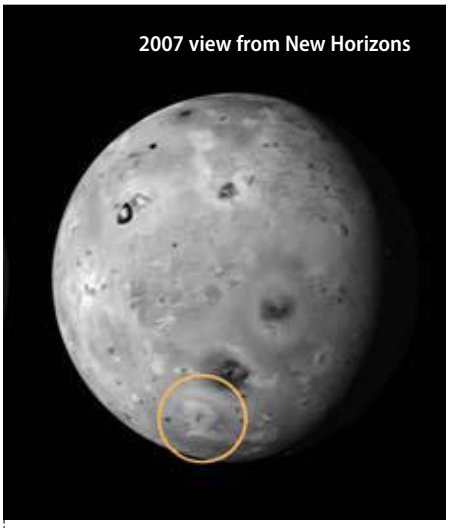
Equally amazing, we saw approximately 10-hour variations in the flux of ions out to at least about 22 million miles (36 million km) from Jupiter. Because the giant planet rotates once in a bit less than 10 hours, this tells us the plasma populations retain a "memory" of their origins in Jupiter's inner magnetosphere, even when they have moved far away.

The plasma ions in Jupiter's magnetotail also appear to have at least two components that come and go: a more energetic population, and a slower, cooler population. All in all, New Horizons' magnetotail traverse provided a rich harvest of data that adds significantly to the storehouse of knowledge about giant-planet magnetospheres — something no one would have expected us to deliver when we first conceived this Pluto mission.

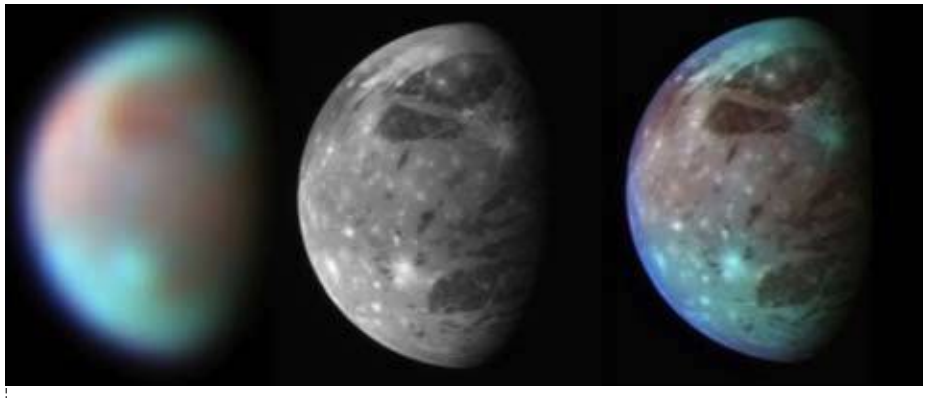
The long trip ahead

The scientific results I've summarized represent just the tip of the iceberg of what we expect to learn by analyzing the full Jupiter dataset over the coming year.

S. Alan Stern *is the Principal Investigator of the New Horizons mission. He works at NASA Headquarters in Washington.*



CIRCLES MARK THE SPOT of a noticeable change on Io over the past 7 years. A Galileo image from 1999 (top) shows little detail in the circled region; to New Horizons, however (below), a new volcanic eruption has created a roughly circular deposit nearly 300 miles (500 km) across.



GANYMEDE'S SURFACE reveals different compositions under the watchful eye of New Horizons. An infrared view (left) highlights those differences, with blue representing fairly clean water ice and brown signifying contamination by dark material. New Horizons best visible-light image appears at center, and a combination of the two appears at right.

COLOR AND STARS BY SIMON JENKS

ICY EUROPA rises above Jupiter's cloud tops 6 hours after New Horizons' closest approach. This image is one of a handful taken primarily for artistic, instead of scientific, purposes.

But we obtained another result that's equally important — we learned how to fly our spacecraft through a complex planetary encounter. Those lessons, including how to plan and rehearse an encounter, will pay off handsomely when we reach Pluto in 2015.

Our science and mission operations teams are so fresh with experience from the Jupiter encounter, we've changed strategy and decided to begin Pluto-encounter planning this year. Originally, we'd planned to do that in 2012, so we could rehearse and work out any encounter-sequence bugs in 2013 and 2014, well in advance of our date with Pluto in mid-2015. Instead, we will perform these tasks in 2007, 2008, and 2009. By moving this activity up, we don't risk losing expertise as the years pass. Of course, it also means we have more work to do in the next couple of years, but the reward will be worth it at Pluto.

As you read these words, this work has already begun. It will culminate in early 2009 with a full dress rehearsal of our Pluto close-encounter sequence on New Horizons.

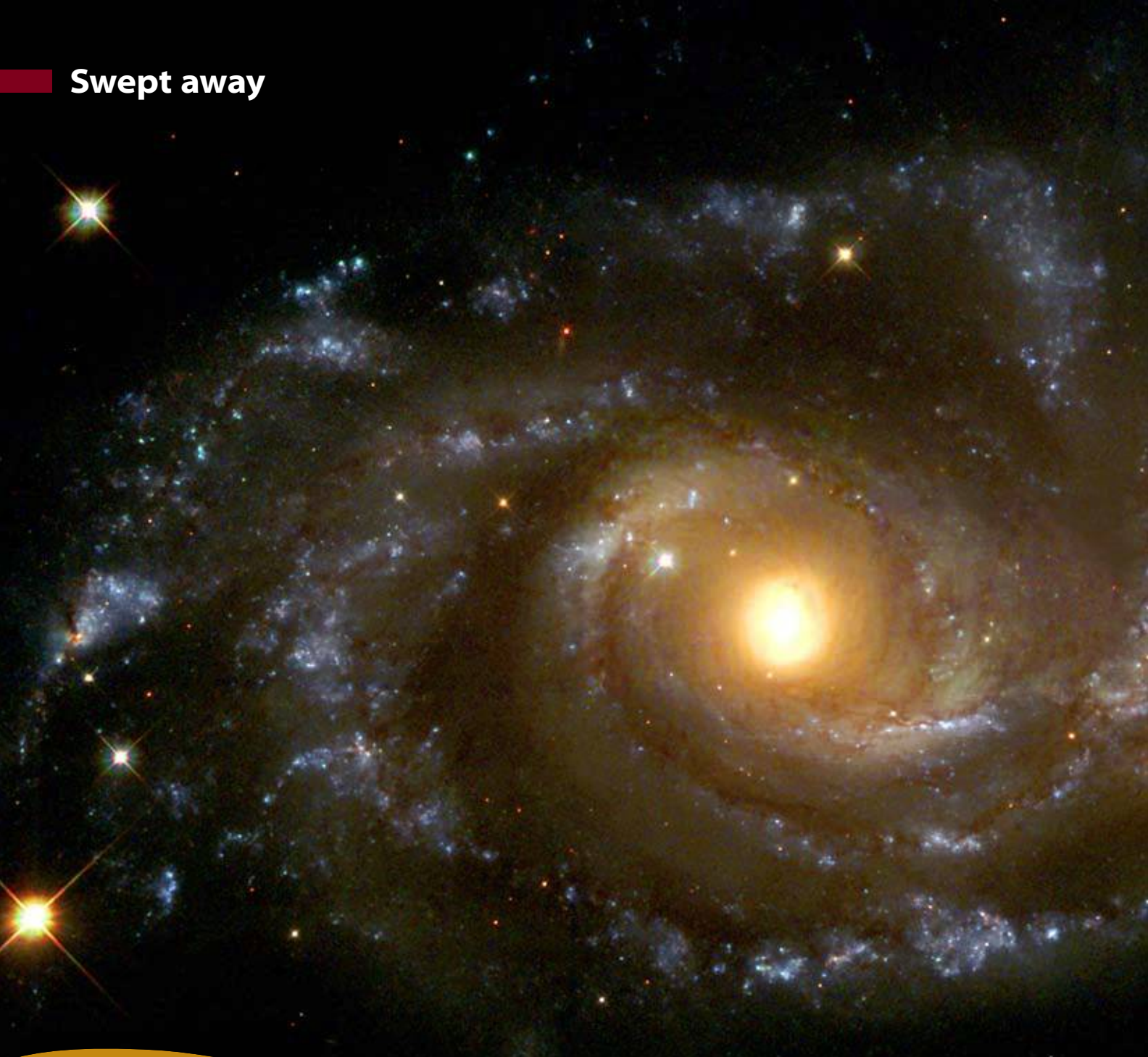
While we plan and then rehearse our Pluto encounter, and in the subsequent years that stretch out to 2014, New Horizons itself will spend most of its time hibernating. The majority of its electronics will be turned off. This will save on spacecraft wear and tear. As a result of this hibernation, most of the spacecraft's electronics will have logged only about 3.5 years of operation by the time we reach Pluto, some 9.5 years after launch.

The first-time exploration of the Pluto system awaiting us will be the most exciting part of the New Horizons mission. For the first time, humankind will see what an ice dwarf planet is like, what a planetary binary is like, and what Pluto's small moons have to tell us about the origin and evolution of our solar system.

It's hard to suffer through almost 8 more years of anticipation for the rewards that our Pluto flyby will deliver, but that is what we must do.

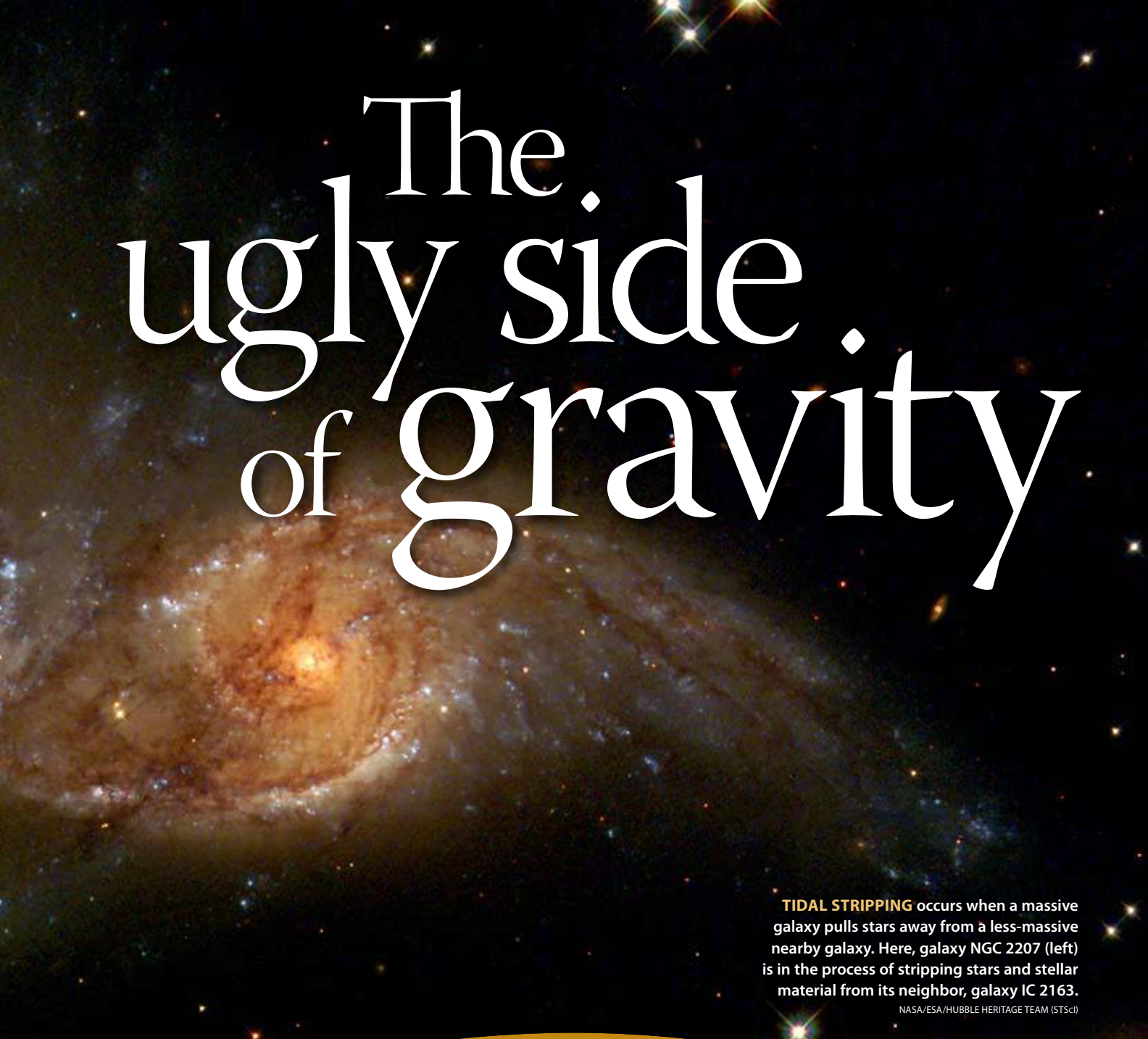
In the meantime, our job on the New Horizons project is to be good stewards of the spacecraft and to plan a knock-your-socks-off scientific encounter for the Pluto system. That is exactly what our team is doing.

Swept away



Earth's ocean tides, Jupiter's comet-splitting power, and galaxies gravity's destructive force. /// BY C. RENÉE JAMES

The ugly side of gravity

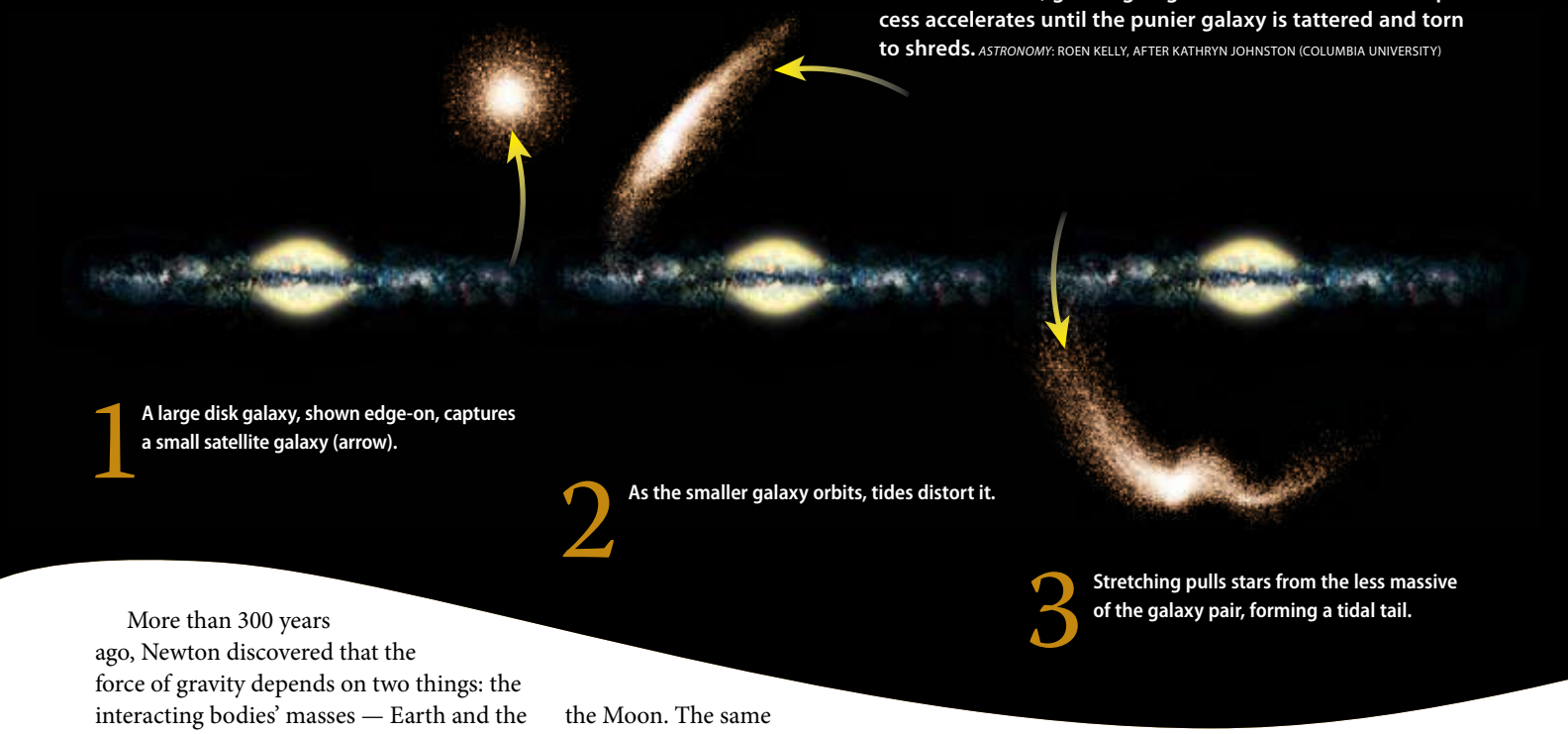


TIDAL STRIPPING occurs when a massive galaxy pulls stars away from a less-massive nearby galaxy. Here, galaxy NGC 2207 (left) is in the process of stripping stars and stellar material from its neighbor, galaxy IC 2163.
NASA/ESA/HUBBLE HERITAGE TEAM (STScI)

stripping stars away from neighbors tell the story of

Gravity is nature's weakest force. This might be difficult to believe when you step gingerly onto a scale, but keep in mind you interact with Earth's entire 6.6 million trillion kilotons of mass in order to have that weight. Gravity is so weak that if it were the only thing holding you together, the faintest whisper of a breeze would tear you apart. Fortunately, your body is also strongly bound at the molecular level. For many objects in the universe, though, gravity is the only force holding them together. And, in some cases, gravity is the force that ultimately tears them apart.

How big galaxies shred small ones


1
A large disk galaxy, shown edge-on, captures a small satellite galaxy (arrow).
2
As the smaller galaxy orbits, tides distort it.
3
Stretching pulls stars from the less massive of the galaxy pair, forming a tidal tail.

TWO GALAXIES orbit one another in this illustration. The larger disk galaxy pulls stars from the smaller satellite galaxy into leading and trailing tails. The larger galaxy strips stars from the smaller, growing larger and more massive. The process accelerates until the punier galaxy is tattered and torn to shreds. *ASTRONOMY:* ROEN KELLY, AFTER KATHRYN JOHNSTON (COLUMBIA UNIVERSITY)

More than 300 years ago, Newton discovered that the force of gravity depends on two things: the interacting bodies' masses — Earth and the Moon, for instance — and their separation. The farther apart the bodies, the weaker the gravitational attraction.

Earth and Moon interact

Objects with mass don't experience gravity's tug uniformly over all their parts. For two orbiting bodies like Earth and the Moon, areas that face each other are also closer to one another and, thus, experience a larger gravitational pull.

As a result, the Moon tugs more strongly on the Moon-facing part of Earth than it does on the opposite side. This leaves a bulge behind on Earth's far side that is symmetric to the bulge pulled up on the Moonward side. Earth also exerts a tidal force on the Moon. The same swollen lunar face always stares at us because Earth and the Moon are tidally locked.

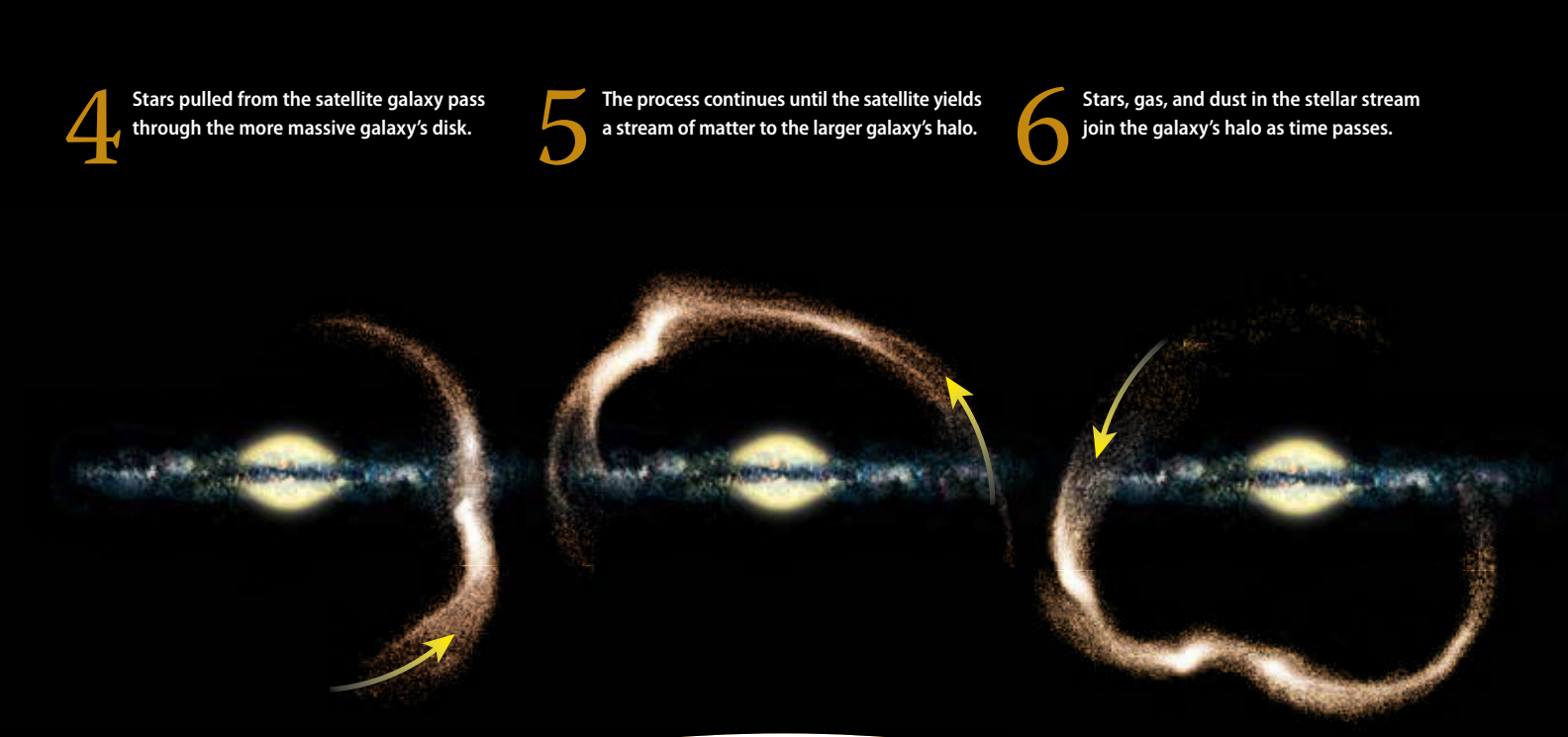
As ocean tides perpetually align with the Moon, which saunters around Earth every 27.3 days, Earth keeps spinning, once every 24 hours. The tidal bulges drag and create friction, which slows Earth's rotation at a rate of 2.3 milliseconds per day per century. That's not enough to change your work schedule, but it is enough to make us toss a leap second into our timekeeping every now and then.

These familiar ocean tides seem anything but destructive, except, perhaps, to sandcastles. Oceans aren't the only things tidal forces affect, though. The terra firma you stand on can rise more than a foot as the Moon passes overhead. The Sun contributes, too, but to a much lesser extent than the Moon because the Sun is much farther away. Twice a month — at New and Full Moon — the Sun and Moon give Earth an extra tidal squeeze. This tidal crunch is sometimes the last bit of stress a fault line can handle before it has to adjust itself. Then we see some indirect tidal destruction in the form of an earthquake.

Monster planet

But the tidal force between Earth and the Moon is insignificant compared to what Jupiter inflicts on its innermost moon, Io.

COMET SHOEMAKER-LEVY 9 experienced tidal disruption when it came close to massive Jupiter. The comet fragmented into at least 21 pieces before plummeting into the planet's dense atmosphere in July 1994. H. A. WEAVER AND T. E. SMITH (STScI)/NASA


4 Stars pulled from the satellite galaxy pass through the more massive galaxy's disk.
5 The process continues until the satellite yields a stream of matter to the larger galaxy's halo.
6 Stars, gas, and dust in the stellar stream join the galaxy's halo as time passes.

Our Moon contains a scant 1 percent of Earth's mass and lies 239,000 miles (385,000 km) away. Io, about 20 percent more massive than the Moon, has to contend with a planet 318 times Earth's mass. And Io is only 23,000 miles (37,000 km) farther away. Additional tidal forces come from the other three Galilean satellites: Europa, Ganymede, and Callisto. Their masses are 0.66, 2.03, and 1.45 Moon-masses, respectively. Each is engaged in its own tidal tug-of-war with Jupiter, and with its neighboring satellites. They all distort Io when their orbital dance around Jupiter brings them within range.

As a result, Io has a tidal bulge reaching hundreds of feet (tens of meters) high and an unstable landscape that spews volcanic plumes more than 100 miles (160 kilometers) into space. Just as our Moon always faces Earth, Io has tried to become tidally locked to Jupiter. But the moon's orbit is too eccentric, and its siblings add stresses that prevent it from achieving synchronous rotation. Io's continual deformation heats its interior and powers its volcanoes. In this erratic terrain, mountains grow and collapse within a few million years.

Although farther from Jupiter, Europa also feels these tidal tugs. But because tidal

C. Renée James *is an associate professor of physics at Sam Houston University in Huntsville, Texas.*

LINKING OCEAN TIDES AND THE MOON

Modern-day astronomers study tidal forces arising from gravitational attraction to help them understand everything from the structure of comets to the evolution of galaxies. But the link between ocean tides and the Moon wasn't always so well known, although ancient philosophers had some interesting ideas as to their cause.

OCEAN TIDES result from the gravitational force between Earth and the Moon. Gravity's pull exists among all objects in the universe. MIKE LE

Over 2,300 years ago, Aristotle seemed to understand the link between the Moon and ocean tides. Unfortunately, he also attributed tidal variations to the sea demon Charybdis.

In 1616, Italian astronomer and physicist Galileo Galilei wrote *Treatise on the Tides*. In it, he sought to divorce natural motions from unseen supernatural forces like sea demons by attributing observable causes to observable effects. He asserted the 25-hour tidal cycle was proof of Earth's rotation and motion around the Sun — an incorrect hypothesis. He ultimately dismissed as mysticism writings by Johannes Kepler (1571–1630) and others that suggested a tide-Moon link.

In 1687, English mathematician and physicist Isaac Newton suggested Earth's tides are the result of gravity — an attractive force between bodies in space that can distort, deform, even break apart massive objects, including our home planet. Newton's breakthrough theory of gravitation, published in 1687's *Principia*, explained the tides as the action-at-a-distance force of gravity. This gravitational force exists between all objects throughout the universe but diminishes as the distance between objects increases.

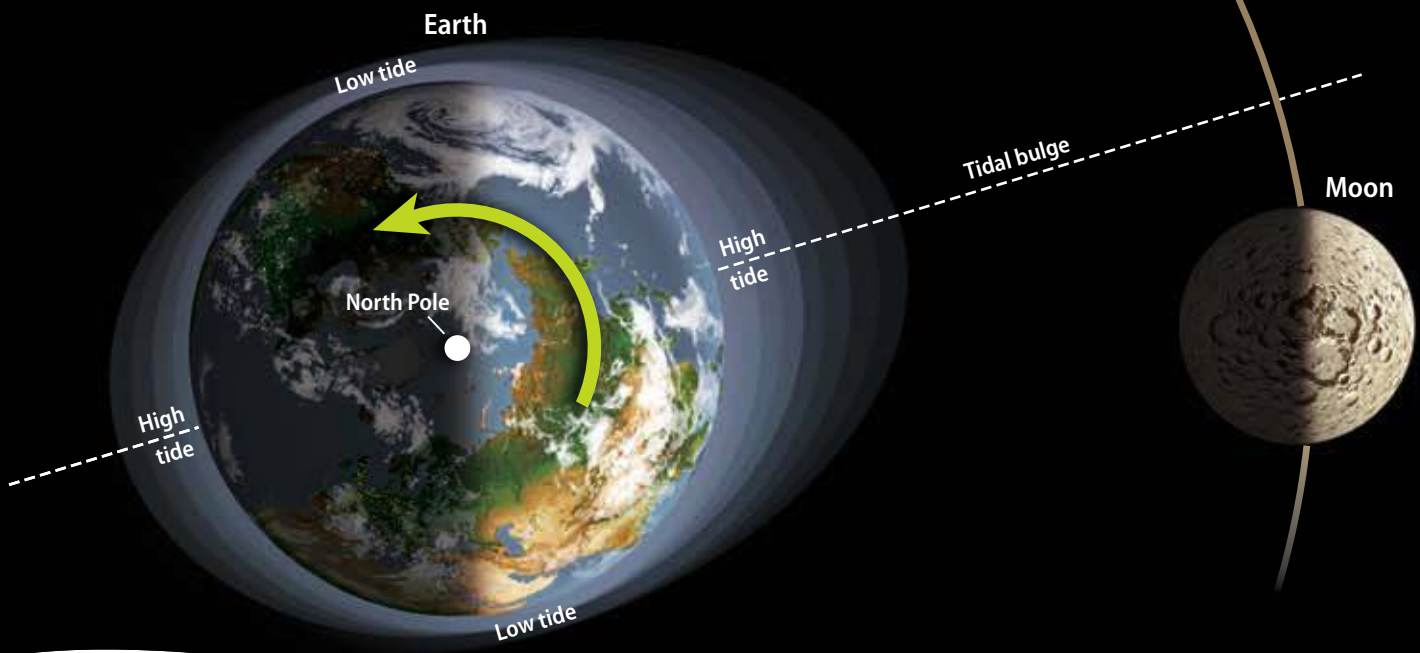
In 1882, Lord Kelvin (1824–1907) spoke on the topic of tidal theory to the British Association at its Southampton meeting. Kelvin noted the periodicity of ocean tides and asserted his belief that "Tides are motions of water on the Earth due to the attractions of the Sun and the Moon."

After years of studing the continuous nature of ocean tides, scientists now know much about the link between ocean tides and the Moon. What scientists have learned about tidal forces help them learn even more about tidal effects in the universe. — *C. R. J.*

The Earth-Moon connection

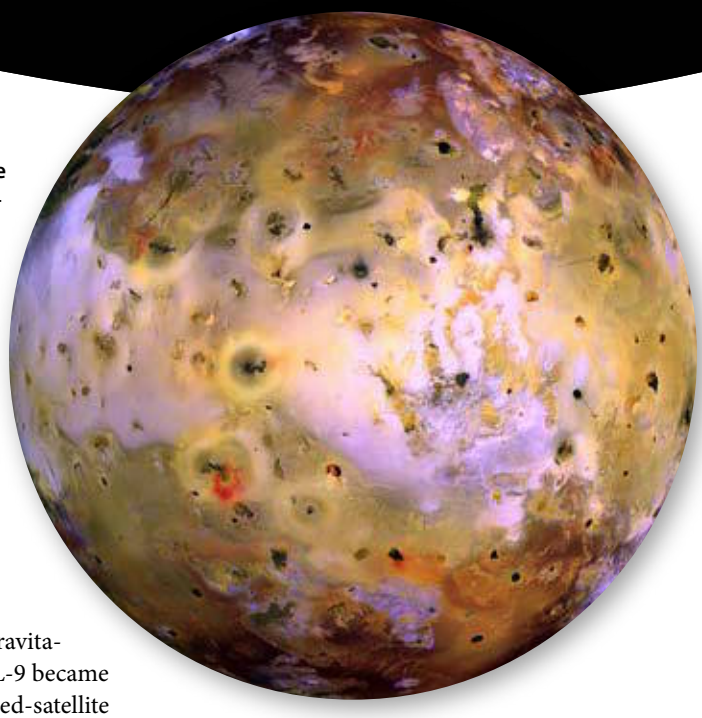
EARTH AND THE MOON are tidally locked in a gravitational dance. As the Moon orbits, it pulls more on closer areas than those farther away. This asymmetrical pulling forms tides on Earth.

ASTRONOMY: ROEN KELLY



forces plummet with increasing distance, Europa experiences gentler stresses. Still, they have helped shape what is quite possibly the most intriguing body in the solar system. The same tidal heating that wreaks havoc on Io apparently makes Europa a cosmic slushy with a 62-mile-thick (100 km) layer of water and ice sealed beneath an icy crust. If there's a place in the solar system with the raw ingredients for life, Europa is it.

Tidal forces become less bearable for objects closer to Jupiter than Io. As objects held together solely by their own gravity come to within about 3.5 Jupiter radii, or 149,129 miles (240,000 km), of the massive planet, they cannot withstand the tidal stresses and break apart like Comet Shoemaker-Levy 9 did in 1994.



IO, Jupiter's innermost moon, feels the full force of Jupiter's tidal pull on one side and that of the massive planet's three large satellites, Europa, Ganymede, and Callisto, on the other. This tidal tug of war makes Io the most geologically active body in the solar system, with mega volcanoes, bulges that rise 300 feet (100 meters), and surface fractures.

NASA/JPL-CALTECH

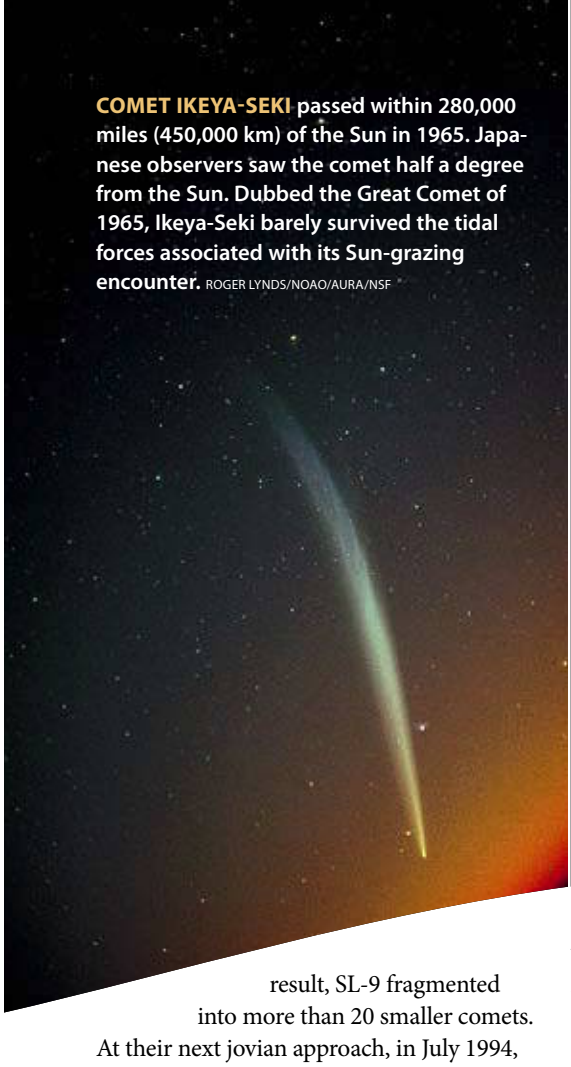
A comet's bad day

Comets that repeatedly pass close to the Sun get destroyed over time. Heat and energetic solar wind slowly erode a comet, littering the solar system with debris that may eventually become a terrestrial meteor shower.

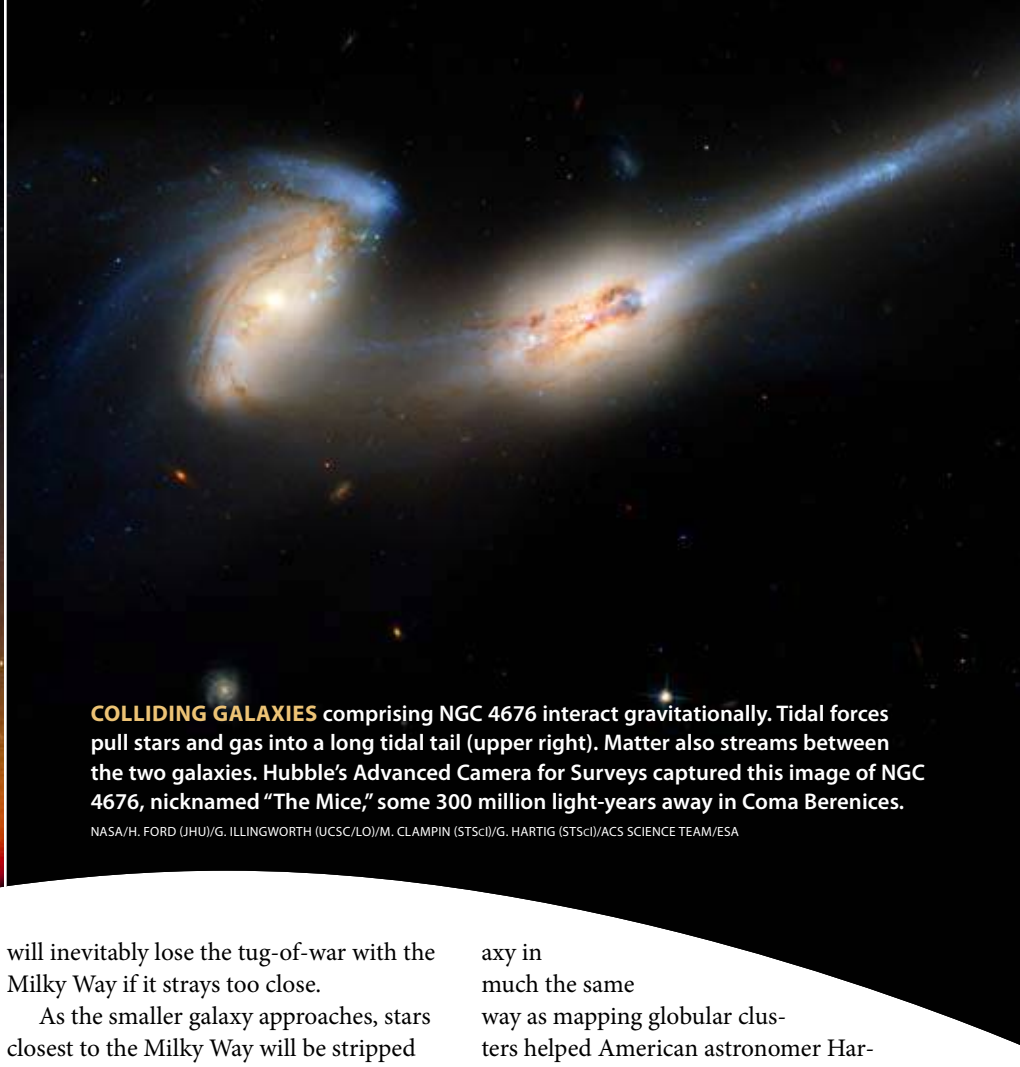
Comet Shoemaker-Levy 9 — a loosely bound heap of ice, rock, and dust — was probably once a short-period, Sun-orbiting comet. Its aphelion swing away from the Sun, likely in the 1920s or 1930s, put it close enough to Jupiter in the early 1970s for the planet's immense gravitational field to capture it. SL-9 became the first jovian comet-turned-satellite known, orbiting the gas giant until its spectacular, disintegrating demise in July 1994.

Before its brush with Jupiter, SL-9 seemed to be in a cometary "safe zone" some 466 million miles (750 million km) away from the Sun. But once caught in Jupiter's gravitational field, it began a highly eccentric orbit around the solar system's largest planet, skimming 24,800 miles (40,000 km) above the cloud tops at its July 1992 closest approach.

The 3-mile-wide (5 km) ball of ice and rock fragmented when it came to within 1.3 times Jupiter's radius. SL-9's Jupiter-facing side was closer to the planet and subjected to a harder pull than its far side. Gravity's larger tug on its Jupiter-facing side surpassed the comet's ability to hold itself together. As a



COMET IKEYA-SEKI passed within 280,000 miles (450,000 km) of the Sun in 1965. Japanese observers saw the comet half a degree from the Sun. Dubbed the Great Comet of 1965, Ikeya-Seki barely survived the tidal forces associated with its Sun-grazing encounter. ROGER LYNDS/NOAO/AURA/NSF



COLLIDING GALAXIES comprising NGC 4676 interact gravitationally. Tidal forces pull stars and gas into a long tidal tail (upper right). Matter also streams between the two galaxies. Hubble's Advanced Camera for Surveys captured this image of NGC 4676, nicknamed "The Mice," some 300 million light-years away in Coma Berenices.
NASA/H. FORD (JHU)/G. ILLINGWORTH (UCSC/LO)/M. CLAMPIN (STScI)/G. HARTIG (STScI)/ACS SCIENCE TEAM/ESA

result, SL-9 fragmented into more than 20 smaller comets. At their next jovian approach, in July 1994, the icy comet fragments dove one by one into Jupiter's thick atmosphere.

The culprit was neither atmospheric friction — which makes for the awesome splintering meteors observed on Earth — nor solar heat. The problem for SL-9 was gravity, a force we usually think of as holding things together. What killed Shoemaker-Levy 9 was Jupiter's tidal force, which, according to Jet Propulsion Laboratory Senior Research Scientist Donald Yeomans, was quite modest and indicates how fragile comets are.

Jupiter is by no means the most massive object around. The Sun has also tidally split comets, including the Great September Comet of 1882 and Ikeya-Seki in 1965. But even the Sun's tidal reach is puny compared to that of an entire galaxy. On this grand scale, we find galaxies throwing their weight around, shredding interlopers and assimilating them.

Galactic tides

The Milky Way, for instance, contains a trillion solar-masses, most of which is invisible. A hapless globular cluster or small galaxy hosting anywhere from a few hundred thousand to tens of millions of suns will inevitably lose the tug-of-war with the Milky Way if it strays too close.

As the smaller galaxy approaches, stars closest to the Milky Way will be stripped away. They will stream away in a tidal tail and settle into orbit about our galaxy. The small satellite galaxy, having lost some of its mass and, thus, some of its self-gravity, will weaken its grip on the rest of its stars. This makes it even easier for the Milky Way to strip more material from it. Eventually, the smaller system will look as though it's been run through a taffy puller, stretched beyond recognition as tidal streams wrap around the Milky Way. Ultimately, the smaller galaxy's material will merge into our own galactic traffic pattern.

This is what appears to have happened throughout much of the Milky Way's history, as well as in most other galaxies. Advances in photometry, wide-field imaging, and computing have helped astronomers discover tidal tails pulled from smaller galaxies and globular clusters amid a noisy background of field stars.

These stretching systems tell us not only about the galaxy being shredded — how much dark matter it contains, for instance — but also about the Milky Way. Because stellar tidal streams maintain a well-behaved galactic orbit, they can help astronomers pinpoint the center of the galaxy in much the same way as mapping globular clusters helped American astronomer Harlow Shapley estimate the extent of the Milky Way nearly 90 years ago.

Astronomers have just begun applying data from tidal streams to determine the Sun's precise distance from the galactic center and the exact orbital speeds of stars in our locale. The Sagittarius Dwarf Galaxy is particularly helpful in this regard because its tidal stream spans nearly a full orbit around the Milky Way. This means it has been completely tidally disrupted over the past 4 to 6 billion years.

Galileo could not have imagined the scope of the force that nudges water up and down beaches. The ideas of a planet reaching out an invisible hand to shred a passing comet or of a galaxy spending Earth's lifetime stretching an interloping star system would have been as fanciful to him as, well, a sea demon.

And the next time it feels as though the forces of life are about to pull you apart, keep an eye on your sandcastle and remember this: Compared to many objects in the universe, you really have it together.

ONLINE EXTRA Watch galaxies get shredded at www.astronomy.com/toc.

An archaeological dig became an astronomical investigation when a 4,200-year-old temple in Peru revealed its secrets.

The Americas' oldest observatory

/// BY ROBERT BENFER AND LARRY ADKINS

THE TEMPLE'S offering chamber contained burned wood that archaeologists dated to 2200 B.C. The ancient building's alignment with sunrise on the summer solstice places it among the oldest astronomical observatories known. LARRY ADKINS

A 4,200-year-old building scientists uncovered in Peru illustrates how ancient peoples were attuned to the heavens. But when a team of archaeologists from Peru and the University of Missouri discovered the ancient temple north of Lima, astronomy was not on the agenda. As they uncovered more of the site, their investigation moved from the ground to the sky. Anthropologist and team leader Robert Benfer called on astronomy professor Larry Adkins to help decipher the find. What the pair discovered was a series of markers that may have been used as an agricultural calendar. The Temple of the Fox appears to be the oldest known structure in North and South America built in alignment with the Sun's position on the solstices.

Robert Benfer *is an anthropologist at the University of Missouri-Columbia who focuses on Latin America.* **Larry Adkins** *has a Ph.D. in physics and teaches at Cerritos College in Norwalk, California.*

The Sun stands still

Each day of the year, the Sun rises at a different point on the eastern horizon. It travels from a maximum southeastern point December 21 to a maximum northeastern point June 21, then it reverses direction for another 6 months.

Sunsets during the year mirror sunrises: They swing from southwest to northwest and back to southwest. The extreme points in December and June are called solstices. In the Northern Hemisphere, June 21 is the summer solstice, while December 21 is the winter solstice (south of the equator, the seasons are reversed).

The Sun rises due east and sets due west March 21 and September 21 — the northern vernal and autumnal equinoxes, respectively. The Sun rises and sets this way because Earth's axis tilts 23.5° with respect to its orbit. This angle is known as the obliquity of the ecliptic. Because of obliquity, the orientation between the Sun and any point on Earth is slightly different each day as our planet orbits our star.

Although prehistoric people didn't know why the positions of sunrise and sunset changed, they were aware of the phenomenon. They built structures aligned with the location on the horizon where the Sun rose at one of the solstices or equinoxes (or at

Tale of the fox

The 4,200-year-old temple archaeologists unearthed north of Lima, Peru, may be the Western Hemisphere's oldest astronomical observatory. Nicknamed the Temple of the Fox because of a mural on its wall, the temple lies in line with the rising Sun on the summer solstice. A sculpture in an adjacent structure faces the opposite direction, toward the setting Sun of the winter solstice. The research team believes the complex functioned as an agricultural calendar. — *Laura Baird*

DARK CLOUDS in the Milky Way, which appears prominently overhead in equatorial regions, take on familiar shapes, like a fox. The stars of the Golden Cat asterism, Kappa (κ) and Iota (ι) Scorpii, precede the dark-cloud figure of the Fox.

ROCK A is aligned with the summer-solstice sunrise as seen from the temple's entry.

ROCK B is aligned with the summer-solstice sunrise as seen from a flat horizon.

ROCK C is aligned with the summer-solstice sunrise as seen from the Temple of the Menacing Disk.

A FOX INCISED on the inside wall of the entry is the temple's namesake. In Peru, the fox is associated with agriculture and irrigation. The rising of the Fox figure heralded the summer solstice, when planting began.

CARVED STONES on an eastern hilltop served as celestial markers. Rock A, sketched here, sits 26° above the horizon. The dark-cloud Fox rising over the rock would have announced the summer solstice. The three stones, each 5 feet (1.5 meters) tall, resemble human faces and face east.

THE TEMPLE is the top tier of a 33-foot-tall (10m) stepped pyramid.

THE TEMPLE of the Fox's offering chamber contained burned plants and twigs, which radiocarbon testing showed to be 4,000 years old. The summer-solstice sunrise December 21, 2220 B.C., would have occurred at 7:58 A.M. at an azimuth of 111°. This is when the Sun would have risen above Rock A, which sits on the hillside at an altitude of 26°.

A MUD-PLASTER sculpture gazes west across the Chillon Valley. The so-called menacing disk has an azimuth of 294°, in line with a hillside fire platform — and the winter-solstice sunset.

THE BUENA VISTA site occupies roughly 15 acres alongside the Chillon River, which floods annually. This archaeological plan shows the central region, including the Temple of the Fox and the Temple of the Menacing Disk.

ASTRONOMY: JAY SMITH, AFTER ROBERT BENFER, ET AL.

THIS FOX MURAL on the temple's inside wall, next to the main entry, is the building's namesake. In Andean mythology, the fox is associated with plant cultivation. LARRY ADKINS

any other periodic astronomical event they deemed important). From a practical point of view, the relationship between the location of sunrise and the seasons was of great value for agriculture, hunting, and fishing. In effect, a structure aligned with a known seasonal sunrise functions as a calendar.

Digging deep

Such celestial phenomena were not in mind when Robert Benfer's team began excavating the Buena Vista archaeological site north of Lima. Buena Vista is just 35 miles (55 kilometers) from the Pacific Ocean and situated on a bleak, rock-strewn hill overlooking a fertile valley watered by the Chillon River. In prehistoric times, as today, the valley was reserved for agriculture, while dwellings and other permanent structures were built on the unproductive hillsides.

As the team uncovered complex structures, it became clear they were entering ceremonial spaces at the top of a stepped pyramid. One room, in particular, appeared to be an offering chamber.

They knew they had found an important site when they discovered a mural on the chamber's wall. It was this artwork, which was subsequently identified as a fox, that gave the structure its name — the Temple of the Fox. Two radiocarbon samples from burned twigs, evidence of burning of offerings, produced the same date: 2200 B.C.

It all lines up

Near the end of the dig's initial phase, one of the archaeologists noticed a stone with the profile of a face on a ridge east of the temple. Benfer measured the stone's azimuth, an angle measured clockwise around the horizon from north, to see if the temple lined up with the rock.

Using a surveyor's transit, he measured an azimuth of 114°. When he turned the transit 180°, it centered on a platform on the western ridge across the valley. This "platform" is a flat spot on the hillside that has evidence of ancient people's fires.

The temple's axis appeared oriented along a line from the platform on the opposite side of the valley, through the structure, to the worked stone on the eastern ridge. The team suspected some purposeful astronomical alignment, so Benfer e-mailed Larry Adkins, a friend and astronomer who had previously visited the site, and asked him to look into this possibility.

A quick calculation revealed 114° was the azimuth for the December solstice sunrise. Because Buena Vista is south of the equator, this is the summer solstice.

Under ancient skies

Immediately, Benfer and Adkins were faced with a challenge. A hill blocks off 26° of the eastern sky as seen from the temple, obscuring the true horizon. So, they had to look for something that rose in the same direction in the early morning and would announce the solstice sunrise. To do this, they needed to know the appearance of the December sky in 2200 B.C.

How did the position of the solstice sunrise then compare to its position today? How were the constellations oriented with respect to the horizon back then?

To answer the first question, they considered that the sunrise azimuth depends on two parameters: the observer's latitude and the obliquity. The latitude remains constant over time, but the obliquity varies between 22° and 24.6° over a 42,000-year period.

Calculations showed that for a 4,000-year time span, the difference in obliquity is only about half a degree. In other words,

ROBERT BENFER

A CARVED STONE on an eastern ridge has a human profile. This is one of three hillside markers, each of which stands roughly 5 feet tall (1.5m). The temple's axis is aligned with the center stone, which indicates where the Sun rose on the summer solstice.

LARRY ADKINS

BUENA VISTA is buried within the hills lining the fertile Chillon River Valley. The temple complex occupies roughly 2 acres in the center of the 15-acre site. Archaeologists have been excavating the temple since 2004 and have just scratched the surface.

compared to today, the position of the solstice sunrise in 2200 B.C. has hardly changed. But something else has.

Precession, the slow wobble of Earth's axis, changes both the position of the constellations with respect to the horizon and the background constellation through which the Sun passes on a given date.

Using planetarium software to precess the sky back to 2200 B.C., Benfer and Adkins didn't see any obvious bright star that might have been a harbinger of sunrise. But they knew the importance of the Milky Way to modern South Americans, revealed in early Spanish chronicles and evident today among indigenous peoples. This led them to consider the role of a dark-cloud figure as the Sun's herald.

When darkness rises

In temperate latitudes, observers know constellation figures based on star patterns. But in equatorial regions, where the Milky Way is often high in the sky, some people construct figures from the dark patches (interstellar dust) embedded in the glowing band. Contemporary dark-cloud figures include the Llama, the Turtle, and the Fox.

The Sun is in the Fox on December 21, so we don't see the figure then. On this date 4,000 years ago, though, the Fox rose about 3 hours before the Sun. And the distinctive asterism of the stars in Scorpius the Scorpion's tail precedes it.

It takes little imagination to visualize a priest standing in the temple next to the fox mural watching the celestial Fox rise, then watching the dark-cloud figure fade into dawn on the summer solstice.

About face

In 2005, the archaeological team made another discovery: a series of rooms adjacent to the original temple where they found rare, three-dimensional sculptures. The most spectacular is a round face made of grass and mud covered with clay that Benfer dubbed the "menacing disk."

This frowning disk faces the fire platform across the valley. Because the platform is in line with the summer-solstice sunrise, the winter-solstice Sun (in June) would have set over this platform. So, while the menacing disk looks at the winter-solstice sunset, the fox mural faces the summer-solstice sunrise. And both the temple and the menacing disk are aligned with stones on an eastern ridge. What does it all mean?

The timing is right

Benfer hypothesizes the entire complex is an elaborate agricultural calendar. Throughout South America, indigenous peoples associated the Fox with plant cultivation and irrigation. The Fox also plays a prominent role in Peruvian creation myths.

Around the time of summer solstice, in December, melting glaciers and rain in the Andes cause the Chillon River to flood. The rising of the Fox figure right before sunrise would have signaled people to plant their crops. The river flow begins to diminish in late March, and the rising of the Fox at the autumnal-equinox sunset would have served as a warning that less water would be available soon. Finally, the winter solstice in June was harvest time, watched over by the scowling face of the menacing disk.

Much remains to be done at Buena Vista, but work there so far has revealed a surprising level of sophistication. At 4,200 years old, the Temple of the Fox predates all other celestially aligned structures in the Americas by 1,000 years — an impressive demonstration of the role the heavens played in the lives of these ancient people. A

ONLINE EXTRA Learn more about dark-cloud figures at www.astronomy.com/toc.

THE OLDEST OBSERVATORY

Radiocarbon dating pegged the Temple of the Fox to 2200 B.C. with calibrated precision dates. This makes it among the oldest astronomically aligned structures in the world, including England's Stonehenge, which dates to c. 2500 B.C.

None of the sites archaeologists have proposed as solstice markers in North America — including Chaco Canyon, New Mexico; Cahokia, Illinois; Medicine Wheel, Wyoming; and Casa Grande, Arizona — are more than 1,000 years old. And no known Olmec site in Mexico dates back more than 3,000 years. Other known solstice-marker sites in Peru date back only 2,000 years.

As the oldest of these structures, the Temple of the Fox is causing historians to rewrite the books: The find suggests a more advanced civilization existed farther inland and earlier than many had suspected. — *R. B. and L. A.*

BY MARTIN RATCLIFFE AND ALISTER LING

AUGUST 07

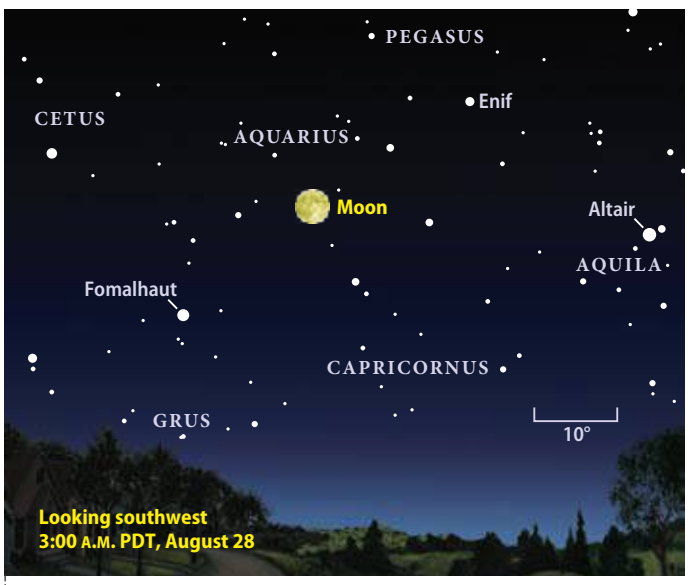
Jupiter rules, meteors flare, and the Moon turns red

MAY'S ECLIPSED MOON, seen here, favored the East Coast. This month, the Moon plunges deeper through Earth's shadow, and the West Coast sees the best show. ANTHONY AYIOMAMITIS

Venus and Saturn slip into evening twilight early this month. Jupiter then rules as the only naked-eye planet, visible low in the south as darkness falls. ☾ Midmonth brings one observing highlight — the Perseid meteor shower peaks.

44 Total lunar eclipse
49 Perseid meteor shower peaks
49 Explore Crater Longomontanus
50 When to view the planets
50 A comet cruises through Virgo
51 Vesta buzzes Jupiter
51 Locate Uranus and Neptune

Visible to the naked eye
Visible with binoculars
Visible with a telescope



LOOK FOR THE STARS of Aquarius as the Moon makes its way through Earth's shadow August 28. *ASTRONOMY:* ROEN KELLY

Another treat comes near month's end — the year's second **total lunar eclipse**.

The spectacular eclipse occurs the morning of August 28. Circumstances favor observers west of the Mississippi, who missed out on the March lunar eclipse. Better still, this event marks the first central lunar eclipse since 2000.

A central eclipse is one where part of the Moon passes through the center of Earth's shadow. This results in a longer-lasting eclipse, and it likely will result in a more darkly colored Moon at totality. The Moon's northern edge passes through the shadow's center, which means its northern half will look noticeably darker than its southern half.

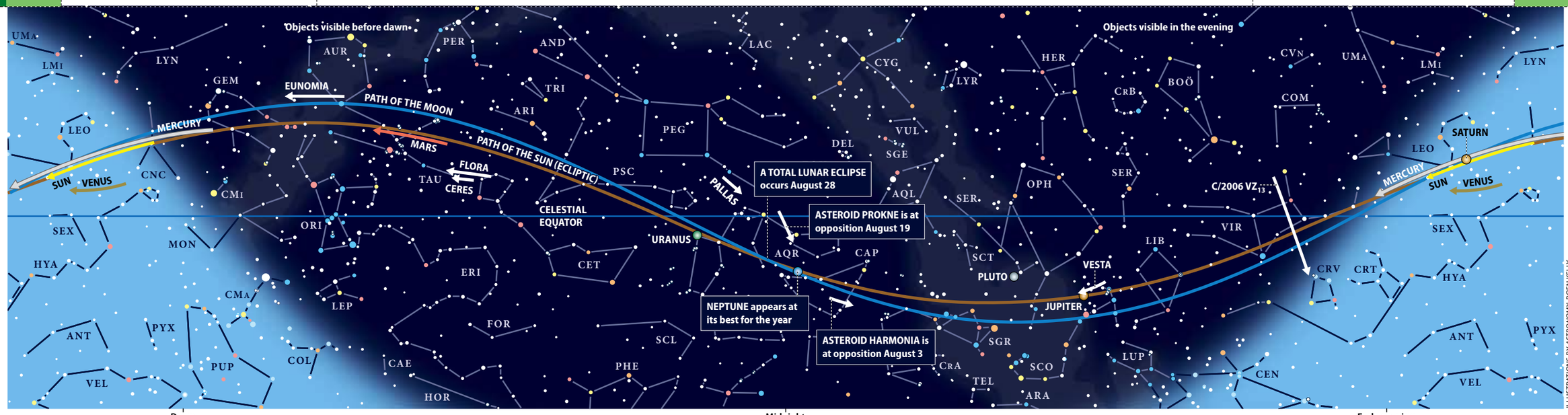
The penumbral part of the eclipse begins at 3:54 A.M. Eastern Daylight Time. The first hint of shadow won't be visible to East Coast observers until at least 4:30 A.M. Watch the Moon low in the southwest as the limb near Oceanus Procellarum gradually darkens.

The umbral eclipse phase begins at 4:51 A.M. EDT. It takes

— *Continued on page 49*

Planets this month

This map unfolds the entire night sky from sunset (at right) until sunrise (at left). Arrows and colored dots show motions and locations of solar system objects during the month.



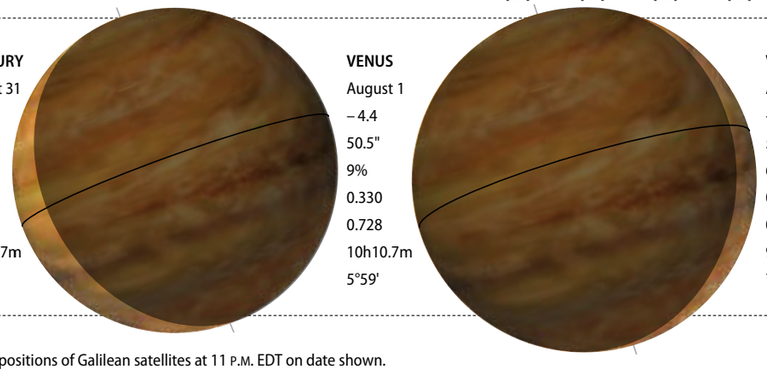
ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

[14] [13] [12] [11] [10] [09] [08] [07] [06] [05] [04] [03] [02] [01]

[31] [30] [29] [28] [27] [26] [25] [24] [23] [22] [21] [20] [19] [18] [17] [16] [15] [14] [13] [12]

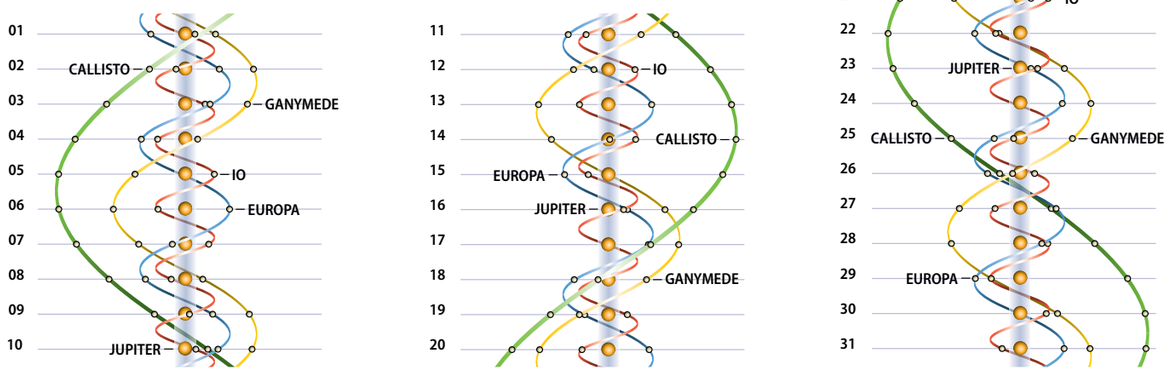
To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.

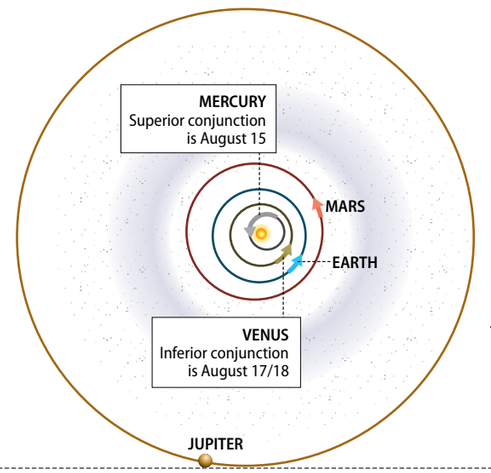
PLANETS	MERCURY	MERCURY	VENUS	VENUS	MARS	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	August 1	August 31	August 1	August 31	August 15	August 15	August 15	August 15	August 15	August 15
Magnitude	−1.1	−0.5	−4.4	−4.4	0.4	−2.3	0.6	5.7	7.8	13.9
Angular size	5.9"	5.1"	50.5"	53.8"	7.5"	40.3"	16.2"	3.7"	2.4"	0.1"
Illumination	75%	91%	9%	6%	86%	100%	100%	100%	100%	100%
Distance (AU) from Earth	1.138	1.330	0.330	0.311	1.250	4.892	10.238	19.177	29.033	30.745
Distance (AU) from Sun	0.312	0.424	0.728	0.727	1.417	5.296	9.231	20.093	30.046	31.328
Right ascension (2000.0)	7h39.1m	11h27.7m	10h10.7m	9h11.9m	4h12.5m	16h33.4m	10h00.7m	23h15.6m	21h31.9m	17h44.8m
Declination (2000.0)	21°40'	4°26'	5°59'	7°50'	20°07'	−21°27'	13°31'	−5°39'	−14°56'	−16°33'



Jupiter's moons

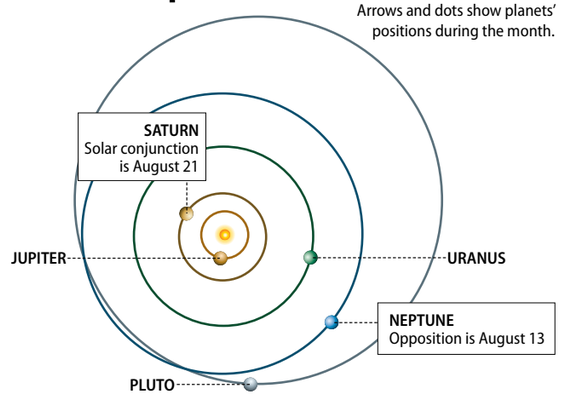
Dots display positions of Galilean satellites at 11 P.M. EDT on date shown. South is at top to match the view through a telescope.





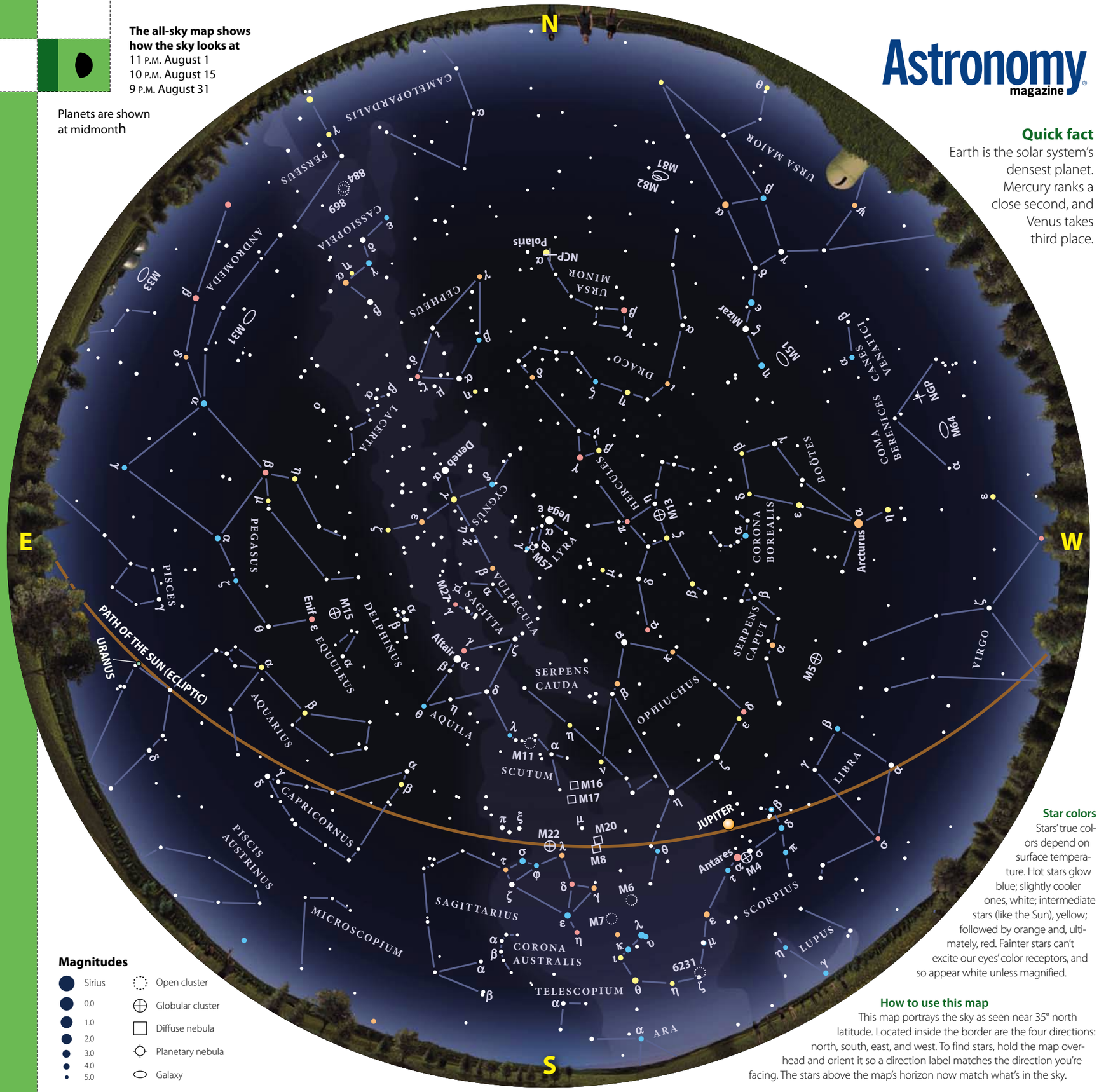
The planets in their orbits

Arrows and dots show planets' positions during the month.



The all-sky map shows how the sky looks at
11 P.M. August 1
10 P.M. August 15
9 P.M. August 31

Planets are shown at midmonth



Magnitudes

Sirius	Open cluster
0.0	Globular cluster
1.0	Diffuse nebula
2.0	Planetary nebula
3.0	Galaxy
4.0	
5.0	

Star colors
Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white unless magnified.

How to use this map
This map portrays the sky as seen near 35° north latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

Astronomy magazine

Quick fact
Earth is the solar system's densest planet. Mercury ranks a close second, and Venus takes third place.

august 07

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
			[01]	[02]	[03]	[04]
[05]	[06]	[07]	[08]	[09]	[10]	[11]
[12]	[13]	[14]	[15]	[16]	[17]	[18]
[19]	[20]	[21]	[22]	[23]	[24]	[25]
[26]	[27]	[28]	[29]	[30]	[31]	

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

01 Mercury passes 6° south of Pollux, 3 P.M. EDT

The Moon passes 2° north of Uranus, 10 P.M. EDT

03 The Moon is at perigee (229,218 miles from Earth), 7:54 P.M. EDT

05 Last Quarter Moon occurs at 5:20 P.M. EDT

06 The Moon passes 6° north of Mars, midnight EDT

12 New Moon occurs at 7:03 P.M. EDT

13 Perseid meteor shower peaks

Neptune is at opposition, 2 P.M. EDT

15 Mercury is in superior conjunction, 4 P.M. EDT

17 Venus is in inferior conjunction, midnight EDT

18 The Moon is at apogee (251,418 miles from Earth), 11:28 P.M. EDT

20 First Quarter Moon occurs at 7:54 P.M. EDT

21 Saturn is in conjunction with the Sun, 7 P.M. EDT

The Moon passes 0.7° south of Antares, 9 P.M. EDT

The Moon passes 6° south of Jupiter, 11 P.M. EDT

23 Mars passes 5° north of Aldebaran, 8 P.M. EDT

27 The Moon passes 1.4° south of Neptune, 5 A.M. EDT

28 Full Moon occurs at 6:35 A.M. EDT; total lunar eclipse

29 The Moon passes 2° north of Uranus, 5 A.M. EDT

30 The Moon is at perigee (226,296 miles from Earth), 8:12 P.M. EDT

ONLINE EXTRA For definitions of terms, visit www.astronomy.com/glossary.

— *Continued from page 44*

an hour for the Moon to fully enter Earth's shadow. But by the time it does, twilight brightens the sky. For observers on the East Coast, the Moon sets while totally eclipsed.

The farther west you go, the higher the Moon's altitude during totality. West of the Rockies, observers see all but the eclipse's final penumbral stages. Totality begins at 4:52 A.M. Central Daylight Time, and mideclipse occurs at 5:37 A.M. CDT.

Try estimating the Moon's darkness at mideclipse. French astronomer André Louis Danjon (1890–1967) devised a simple scale for comparing the depth of lunar eclipses. It runs from 0 (the Moon is almost invisible) to 4 (the Moon is a bright, coppery red). See sunearth.gsfc.nasa.gov/eclipse for more details.

The Midwest will see totality in a gradually brightening sky, with the Moon 6° high by totality's end. From cities like Denver, perched along the Great Divide's eastern edge, observers may find mountains block the view during the eclipse's later stages.

The West Coast will see the eclipse in its entirety and high in the sky, well placed for observing. In Hawaii, the eclipse occurs near local midnight August 27/28.

Venus and **Saturn** make brief appearances in the first few days of August, but the planetary duo soon succumbs to evening twilight. Venus is quite easy to spot at magnitude –4.3, but the planet lies only 2° high half an hour after sunset.

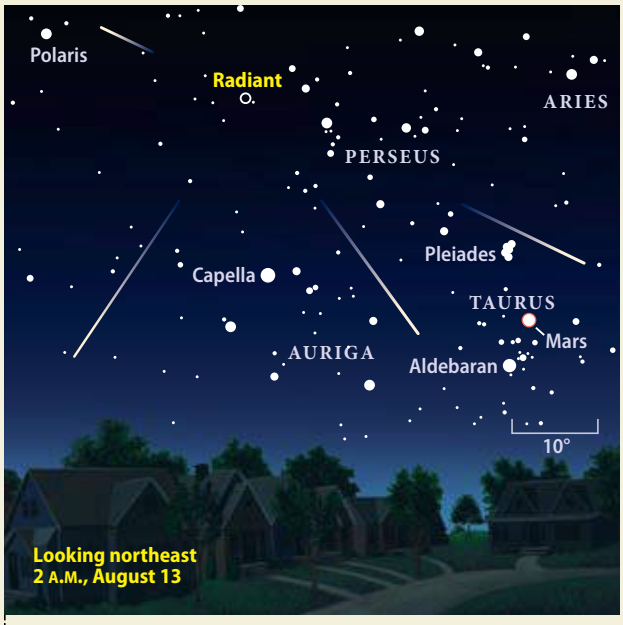
Martin Ratcliffe *is the former president of the International Planetarium Society.* **Alister Ling** *is a meteorologist for Environment Canada.*

THE PERSEIDS POP IN A MOONLESS SKY

The Perseid meteor shower's annual August 12/13 peak occurs during New Moon. Moonlight won't wash out faint meteors, which makes this an especially good Perseid year.

Warm weather and good displays make the Perseids the year's best-observed meteor shower. The activity begins July 17 and lasts through August 24. Meteor rates slowly rise to a peak over North America on the morning of August 13, although significant activity occurs within a day of the shower's peak.

The radiant lies in the constellation Perseus, which rises in the late evening and is well placed by 11 P.M. local time. Like most meteor showers, Perseid activity increases during the early morning hours, when Earth turns skywatchers into the oncoming stream of comet debris.



THE METEORS FLY August 12/13, when the Perseid meteor shower reaches its peak. Observers at a dark site should average a "falling star" each minute. *ASTRONOMY:* ROEN KELLY

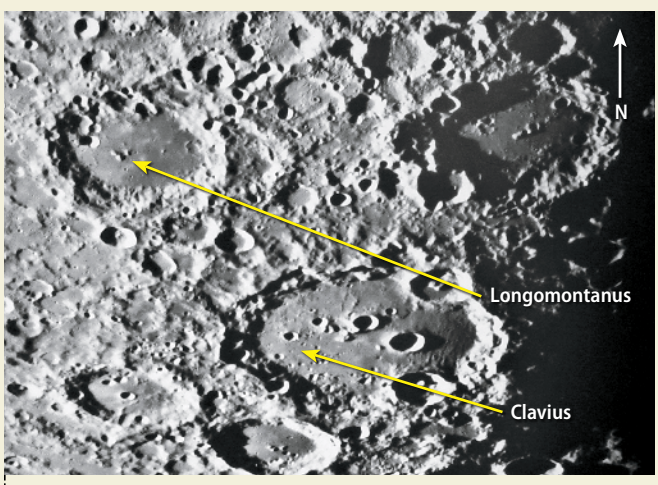
The International Meteor Organization (www.imo.net) predicts two peaks August 13. The first, which is predicted to occur around 4 A.M. EDT, is best for North Americans. Normal rates of 50 to 60 meteors per hour may briefly double.

SHADOWPLAY IN LONGOMONTANUS

Ancient impact craters pepper the Moon's rugged southern highlands. Bright Tycho is one of the youngest, and nearby Clavius is one of the oldest.

Northwest of Clavius lies another large, ancient crater — Longomontanus. The walls of this 90-mile-wide crater have been pummeled repeatedly by later impacts. On the northern rim, many of these craters overlap.

The crater is nearly 3 miles deep. Watch the walls' shadows creep along the crater's floor during sunrise, around the time of First Quarter. As the Sun illuminates the crater, a collection of central peaks appears in the floor's center.



WATCH SHADOWS morph across the floor of 90-mile-wide Longomontanus Crater this month.

Sunrise at Longomontanus begins August 21. This is a good time to grab your first view of this ancient impact site.

Watch the crater over several nights. Changing shadows will give it a different look each time you view it.

/// WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Jupiter (south)	Mars (east)	Mercury (east)
Saturn (west)	Jupiter (west)	Mars (southeast)
Uranus (east)	Uranus (southeast)	Uranus (southwest)

Saturn is a difficult object to view at magnitude 0.5 and an altitude of only 4°. The ringed planet lies 9° to Venus' right.

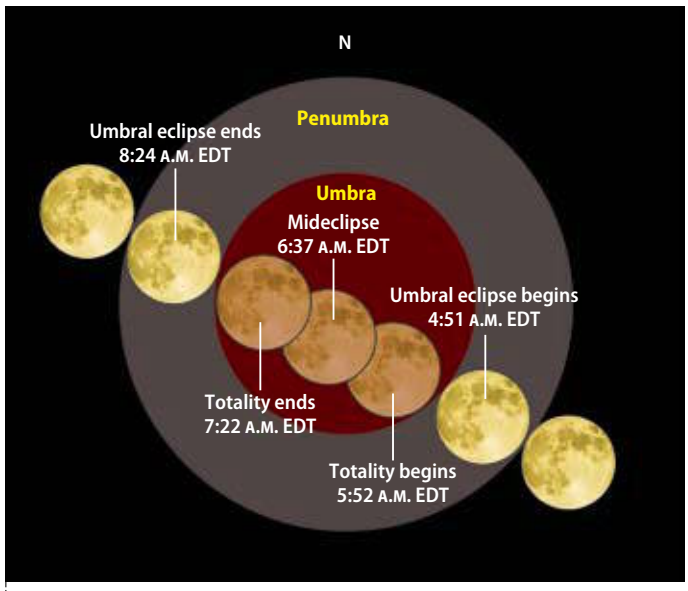
Jupiter dominates the southern sky. Antares, the brightest star in Scorpius, helps call attention to the planet because it lies 5° south of Jupiter. Even casual observers should notice the pair's contrasting colors. Jupiter reflects sunlight and, consequently, appears yellowish. Antares, a red-supergiant star glowing with a surface temperature of less than 3,000 Kelvin, looks distinctly orange.

Jupiter is at its highest — only 30° — right after sunset. The planet's 42"-diameter disk is always a good telescopic target, with dual equatorial cloud belts that are easy to see. Jupiter's disk is full of even finer features. Giant storms like the Great Red Spot, and the new Red Spot, Jr., are regularly on view, although not every night.

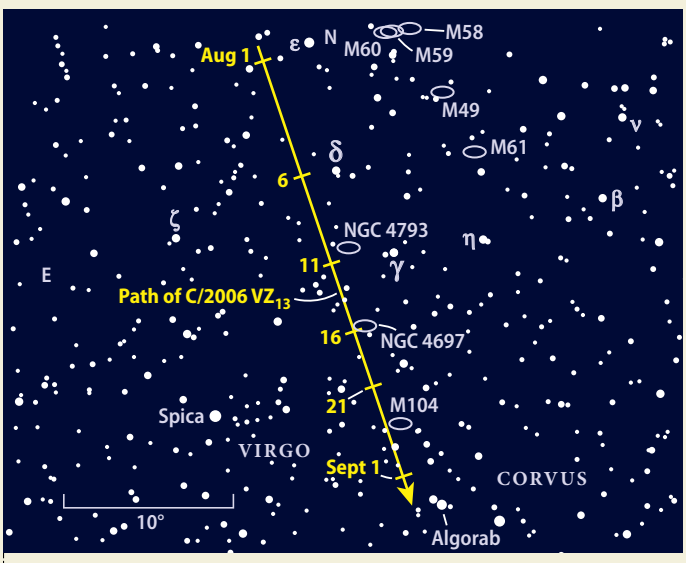
The planet's fast rotation period of 9 hours and 50 minutes brings different features into view each evening. Careful viewing may reveal the motion of individual features in as little as 15 minutes.

The four Galilean moons are on show each night. Occasionally, one or more may hide in Jupiter's shadow (an eclipse) or travel behind (an occultation) or in front of (a transit) the disk. An attractive arrangement occurs August 21, when the First Quarter Moon stands less than 2° from Antares.

This is a great time to challenge yourself by seeking out those other gas giants, Neptune and Uranus. To find **Neptune**, grab 7x50 binoculars and center Iota (ι) Capricorni in the field.



THE LUNAR ECLIPSE August 28 will give observers 90 minutes of totality — 15 minutes more than the eclipse last March. The reason: The Moon penetrates more deeply into the darkest part of Earth's shadow this month. *ASTRONOMY:* ROEN KELLY



COMET VZ_{13} (LINEAR) glides through Virgo in August. The fading comet slips past many galaxies of comparable brightness. Compare them, and you'll soon see why Charles Messier decided to catalog galaxies as "comet-nots." *ASTRONOMY:* ROEN KELLY

A COMET'S MESSIER MASQUERADE

Comets give observers a great way to test their powers of observation. Superficially, an average comet looks much like a galaxy — faint, round, with a bright core fading to a diffuse edge.

This similarity between some deep-sky objects and comets is why Charles Messier (1730–1817) began cataloging "comet look-alikes" 230 years ago. Little did he realize the objects he recorded in Virgo were actually whole galaxies like our own.

Comet C/2006 VZ_{13} (LINEAR) courses through Virgo this month, and it passes by many galaxies. Now glowing at around magnitude 11, VZ_{13} is a modestly challenging object in a 4-inch scope from dark country skies during the month's first half.

Can you spot the comet's faint tail at low power? We see VZ_{13} broadside, so any tail should be well defined.

Increase the magnification to study the inner coma's shape. The bow shock where the solar wind pushes back the comet's gases may give sharp definition to the coma's leading edge.

Compare VZ_{13} to the many nearby galaxies, like the Sombrero Galaxy (M104), M49, M61, NGC 4753, and NGC 4697. By the next waning Moon, Comet LINEAR will have faded into the south. Take a look while you can.

VESTA BUZZES GIANT JUPITER

By month's end, asteroid 4 Vesta will be an easy find in binoculars as it scoots just north of Jupiter. It's only marginally more difficult to spot earlier in the month, for the space rock lies just a binocular field to the planet's right. Vesta shines more brightly than most of the starry background in this sparse sky region.

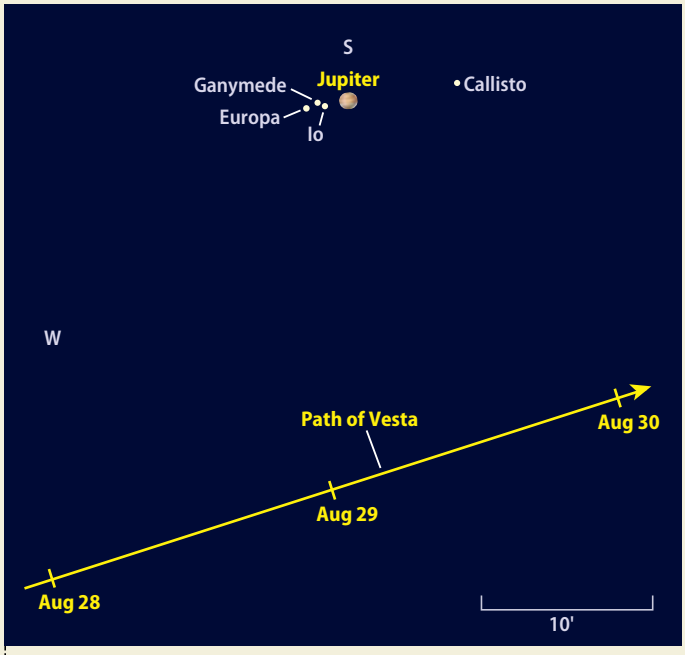
Vesta appears to move faster than Jupiter because it's closer to Earth and has a higher orbital speed. The asteroid's nightly motion is relatively easy to detect, but seeing it shift in a couple of hours is a bit tougher.

A handy guidepost lies just north as August opens. On the 18th, Vesta is a mere 8′ south of 4th-magnitude Psi (ψ) Ophiuchi. During the last week of August, Vesta courses through the same low-power field as Jupiter. The asteroid slides from northwest to northeast as it buzzes the giant planet.

Avoid trying for Vesta August 21. The waxing gibbous Moon will be grazing the orange giant Antares just a few degrees away.

Vesta, a 300-mile-wide rock, was discovered visually by Heinrich Olbers (1758–1840) March 29, 1807. The Arizona-sized asteroid is the first target of NASA's Dawn mission. Launched in early July, Dawn will use its ion engine and a 2009 gravity assist from Mars to reach Vesta in 2011. The probe will remain for 8 months, then move on to dwarf-planet Ceres.

What a way to celebrate Vesta's 200th year in astronomers' catalogs!



ASTRONOMY: ROEN KELLY

VESTA GIVES observers a telescopic treat in late August. The asteroid slips north of Jupiter close enough that a low-power eyepiece can include both objects. This illustration shows Jupiter and its moons as they appear at 10 P.M. EDT August 29.

Neptune lies in the same field, less than 3° to the star's northeast. The outermost major planet reaches opposition August 13 and glows at magnitude 7.8. Its tiny, 2.4″-diameter disk requires modest magnification — at least 100 times — to discern. The best views are near midnight, when Neptune lies high in the south.

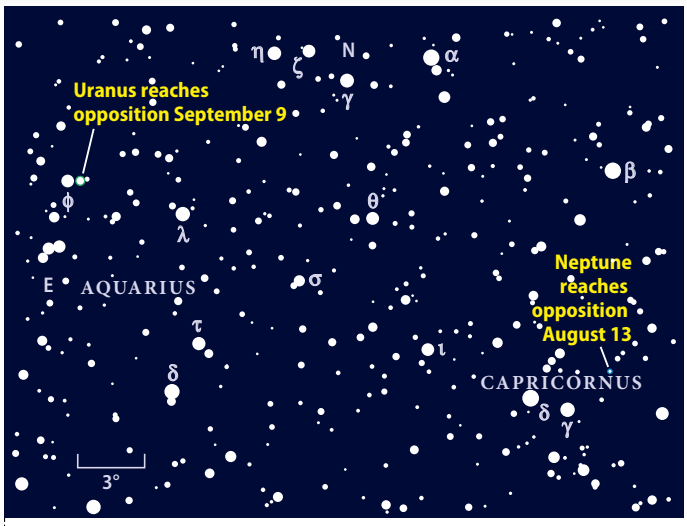
Uranus is easier to spot than Neptune, but you'll have to wait an hour after Neptune rises to see it. Uranus is visible after 10 P.M. local time August 1, and 2 hours earlier August 31. Let the stars in eastern Aquarius reach at least 10° altitude before you try for the seventh planet. The planet glows brightly — for Uranus — at magnitude 5.7. It lies less than a degree northeast of Phi (ϕ) Aquarii, an easy 4.2-magnitude star. Both can be seen using the unaided eye.

Throughout August, Uranus' motion on the sky carries it closer to Phi. The planet lies due north of the star August 24, when a mere 15′ — half the diameter of a Full Moon — separate them. Next month, the seventh planet reaches opposition, putting on its best show for 2007.

Pluto lies 7.6° northeast of the Trifid Nebula (M20) and 3.7° northeast of the fine open star cluster M23. Both of these landmarks will help telescopic observers find the correct field of view. But spotting the magnitude 14 object is more challenging. You'll need a star chart that extends to a similar magnitude, at least a 10-inch scope, and very dark skies to pull it off.

Mars is getting brighter as the planet approaches its year-end opposition. Shining at magnitude 0.5, the Red Planet makes a spectacular addition to Taurus. Telescopically, though, the martian disk spans only 7″.

In early August, Mars skirts south of the Pleiades star cluster. The combination of Mars, Aldebaran — Taurus' brightest star — and Orion rising in the southeast makes a striking early-morning sight. Look for the waning Moon standing 7° northeast of Mars and 5° east of the Pleiades August 7. Mars, at magnitude 0.3 by August 31, brightens throughout December.



THE OUTER GAS GIANTS, Uranus and Neptune, lie about 25° apart this year. Neptune is brightest August 13, Uranus in early September. Use binoculars to spot them. *ASTRONOMY:* ROEN KELLY

Early risers may catch a brief view of **Mercury** in the predawn sky during August's first week. The planet rises right after Castor and Pollux, Gemini's brightest stars. On August 1, Mercury shines at magnitude –1.0 and lies 6° below Pollux. Mercury, rising later each subsequent dawn, brightens to magnitude –1.2 by August 4.

By then, the gap between Pollux and Mercury has increased to 8° and the planet rises 45 minutes before the Sun. After August 8, Mercury is lost in the Sun's glare.

This list of glowing hydrogen clouds provides rewarding targets for eye and camera alike. /// **BY MICHAEL E. BAKICH**

Take the Sharpless Catalog challenge

Many amateur astronomers have moved beyond the "standard" observing lists (like Messier and Caldwell). These intrepid observers have discovered the Sharpless Catalog, a list of more-challenging deep-sky objects. Most Sharpless targets lie beyond the visual range for all but the largest amateur telescopes. Fortunately, charge-coupled device (CCD) technology has made this catalog more "user-friendly," providing realistic targets for today's astroimagers. A 6-inch telescope with an attached CCD camera can reveal most Sharpless objects. And, as the images included here reveal, the Sharpless Catalog contains gems that are intricate, delicate, and beautiful.

His first catalog

In 1953, 27-year-old Stewart Sharpless compiled his first catalog of galactic areas rich in ionized hydrogen — or HII — and

— *Continued on page 57*

ASTRONOMER, CATALOGER, AND EDUCATOR

Stewart L. Sharpless is a professor emeritus of astronomy at the University of Rochester in New York. While attending college, Sharpless worked with fellow University of Chicago graduate students Don Osterbrock and William W. Morgan to prove the existence of spiral arms in the Milky Way. They demonstrated the arms' existence using precise distances of O and B stars obtained from spectral classifications. — *M. E. B.*

ADAM BLOCK/NOAO/AURA/NSF

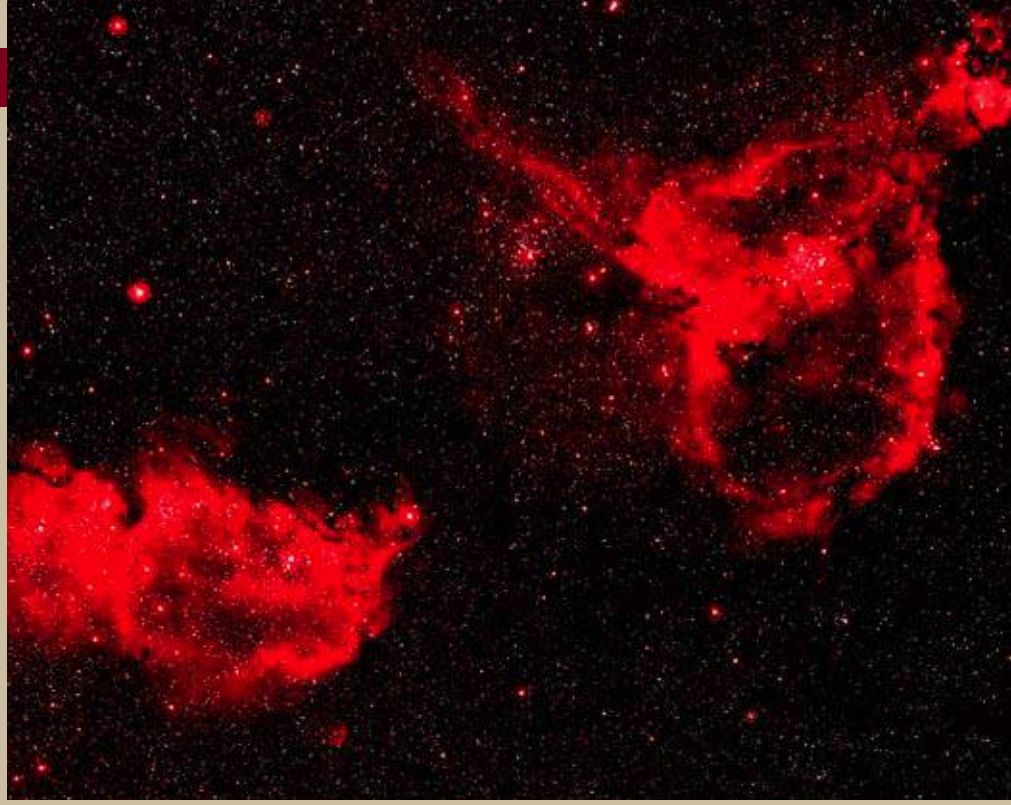
SHARPLESS 2–71 in Aquila may look like an HII region, but it's actually a complex bipolar planetary nebula. Its convoluted nature probably stems from the fact that the central star is a binary system in which the companion star eclipses the primary every 12 hours.

SHARPLESS 2–54 in Serpens measures 140' across — more than 4 Full Moons side by side. The full extent of Sh 2–54's nebulosity contains the young, magnitude 6.5 open star cluster NGC 6604. The nebula appears irregular, filamentary, and reasonably bright. GEORGE GREANEY

SHARPLESS 2–101 in Cygnus sits a bit more than ½° northeast of Eta (η) Cygni. This complex object, which measures 20' across, contains abundant dark nebulae in the form of dark lanes and isolated patches. Sh 2–101's light shines faintly, so use a large telescope to search for it. Look for one blue and two bright orange stars within the nebulosity. BRIAN LULA

Sh 2–229 (The Flaming Star Nebula) ADAM BLOCK/NOAO/AURA/NSF

Sh 2–25 (The Lagoon Nebula) JACK HARVEY AND TOM DOUGHTERY/ADAM BLOCK/NOAO/AURA/NSF



Sh 2–190 (The Heart Nebula) JASON WARE

Sh 2–279 (The Running Man Nebula)
PETER SPOKES/ADAM BLOCK/NOAO/AURA/NSF

Sh 2–277 (The Flame Nebula) JASON WARE

Sh 2–252 (The Monkey Head Nebula) MARK HANSON

Sh 2–298 (Thor's Helmet)
PETER AND SUZIE ERICKSON/ADAM BLOCK/NOAO/AURA/NSF

Sh 2–105 (The Crescent Nebula) BOB AND JANICE FERA

Sh 2–45 (The Omega Nebula)
ADAM BLOCK/NOAO/AURA/NSF

Sh 2–125 (The Cocoon Nebula)
JULIE AND JESSICA GARCIA/ADAM BLOCK/NOAO/AURA/NSF

Sh 2–49 (The Eagle Nebula)
BILL LOFQUIST/ADAM BLOCK/NOAO/AURA/NSF

THE 20 BEST SHARPLESS OBJECTS

Sh 2–117 (The North America Nebula)

ADAM BLOCK/NOAO/AURA/NSF

JIM AND JANET CASTANO/ADAM BLOCK/NOAO/AURA/NSF

Sh 2–30 (The Trifid Nebula)

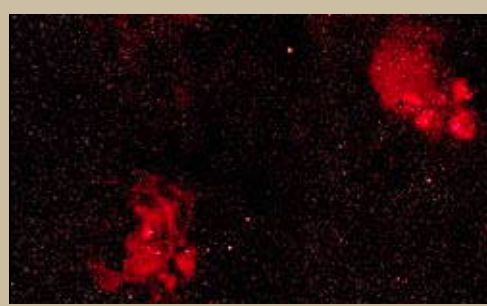
Sh 2–220 (The California Nebula)
ADAM BLOCK/NOAO/AURA/NSF

DANIEL B. PHILLIPS

Sh 2–155 (The Cave Nebula)

Sh 2–184 (The Pac-Man Nebula) JASON WARE

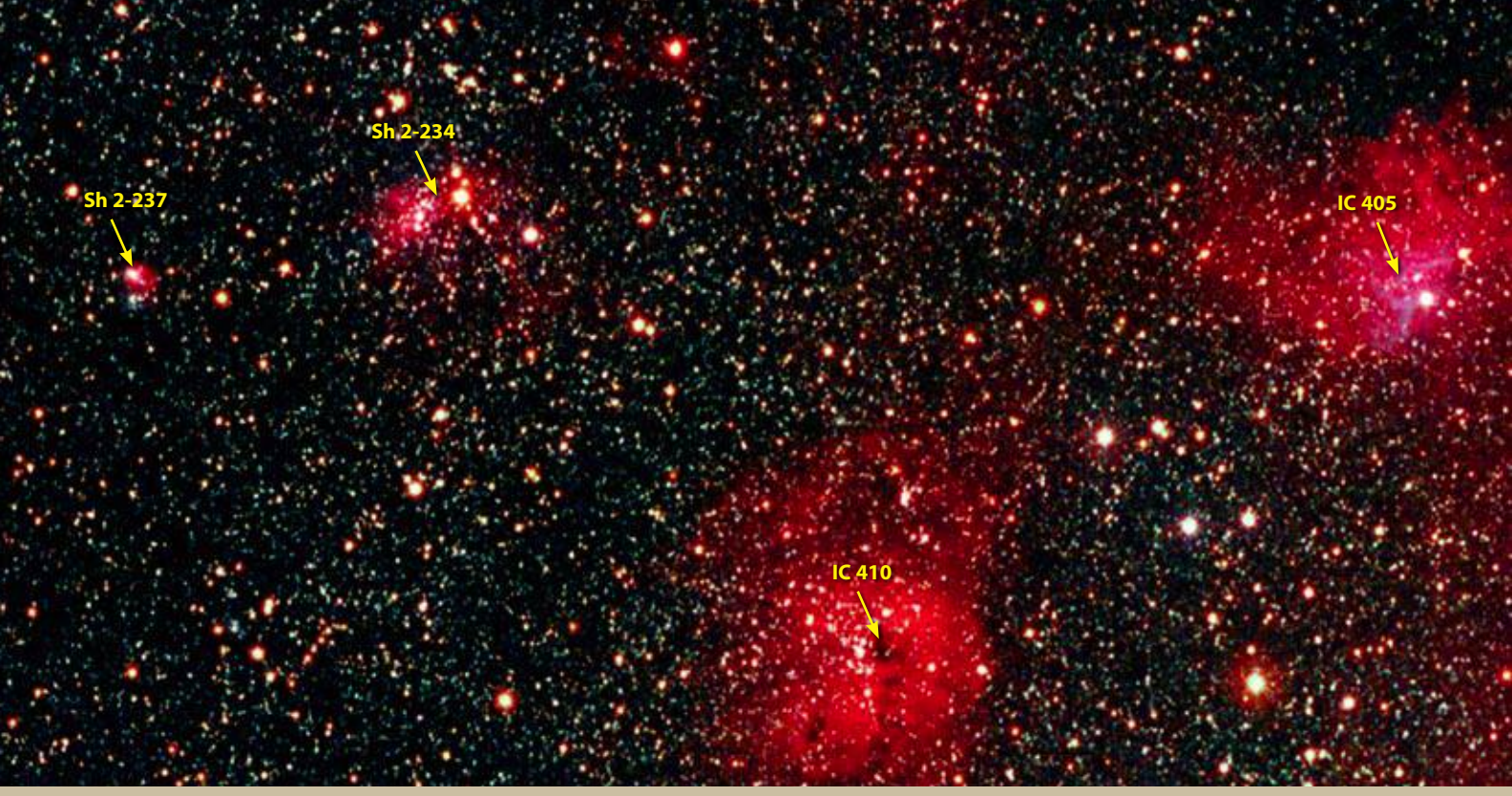
Sh 2–273 (The Fox Fur Nebula) R. JAY GABANY



Sh 2–8 (The Cat's Paw Nebula) GEORGE GREANEY

Sh 2–6 (The Bug Nebula) ADAM BLOCK/NOAO/AURA/NSF

Sh 2–275 (The Rosette Nebula) ADAM BLOCK/NOAO/AURA/NSF



SHARPLESS 2–237 and Sharpless 2–234 lie within 9' of one another in Auriga. It's understandable that most observers and imagers overlook these objects in favor of two brighter nebulae — IC 410 and IC 405. Sharpless 2–237 lies about 6,000 light-years away and measures 12 light-years wide. Sharpless 2–234 lies 7,500 light-years away and measures 26 light-years across. CHRIS SCHUR

CHUCK VAUGHN

SHARPLESS 2–157 lies in Cassiopeia about 2° southwest of open cluster M52 and the Bubble Nebula (NGC 7635). A small concentration of glowing gas forms a tiny but bright part of this otherwise faint nebula.

CHRIS SCHUR

SHARPLESS 2–132 in Cepheus lies 1° southeast of Epsilon (ε) Cephei. The nebula's brightest part — the only section for visual observers — measures roughly 40' by 30'.

CHRIS SCHUR

SHARPLESS 2–242'S most noticeable feature is the color gradient, ranging from a crimson on the right to a rich pink on the left. The varying distance of the nebulosity to the star exciting it creates this effect. Sh 2–242 measures 7' across.

CHRIS SCHUR

SHARPLESS 2–188 proves Sharpless wasn't infallible. It's not an HII region, but rather a diffuse planetary nebula.

CHRIS SCHUR

SHARPLESS 2–261 glows faintly in northern Orion. If you want to observe it visually, use at least a 20-inch scope.

SHARPLESS 2–112 in Cygnus lies just 1.3° west-northwest of Deneb (Alpha [α] Cygni). An easy object to view through a 10-inch telescope, Sh 2–112's rectangular shape shows brighter regions to the north and west. CHRIS SCHUR

— *Continued from page 52*

hot stars. The cataloged objects span the Milky Way from eastern Cassiopeia to Scorpius, and all objects fall within a few degrees of the galactic equator.

Sharpless based his first survey on a series of photographic (National Geographic-Palomar Observatory Sky Survey [POSS]) plates taken with the 48-inch Samuel Oschin Schmidt camera at Palomar Mountain. By the time Sharpless compiled his second catalog, the POSS survey was complete, having started in 1950 and finished in 1957. The plates covered the entire northern sky down to declination –27°. He wrote, "This catalogue is designed to serve as a finding list for radio and optical astronomers as well as a source of diameters and brief descriptions of HII regions."

Sharpless preferred the term "HII region" rather than "emission nebula." He said, "An HII region is an entity defined not only in terms of the ionized gas but also in terms of the hot stars which are responsible for the ionization."

Michael E. Bakich *is a senior editor of* Astronomy.

Cataloging these objects required Sharpless to judge whether isolated patches of nebulosity belonged to the same region. He used the positions of the bright stars ionizing the gas to determine this. He also tried to eliminate all reflection nebulae by comparing the two sets — red sensitive and blue sensitive — of POSS plates. (Because of their bluish color, reflection nebulae appear much brighter on the blue plates.)

The second catalog

In 1959, while working at the U.S. Naval Observatory, Sharpless published his catalog's second and final version. It contains 313 HII regions north of declination –27°. This catalog is *the* Sharpless Catalog.

A year later, astronomers Alexander W. Rodgers, Colin T. Campbell, and John B. Whiteoak, working at Mt. Stromlo Observatory in Australia, published a similar catalog for the Southern Hemisphere. Known as the RCW catalog, the compilation contains 182 objects, roughly 50 of which also appear in the Sharpless Catalog.

Sharpless used the data he acquired in a variety of ways. He even "saw" the distribution of matter within the Milky Way's arms. He wrote, "The decrease in average angular diameter from l [galactic longitude] = 315° to l = 5° is in keeping with an inner spiral arm [Sagittarius arm] going off in perspective in the direction of Scutum; and the increase in angular sizes from l = 15° to l = 55° agrees qualitatively with the curvature of our own spiral arm. The relative scarcity of nebulae between l = 92° and 102°, and between l = 56° and 66°, is indicative of a rather spotty distribution of HII regions in the Perseus arm."

Objects listed in the Sharpless Catalog have "Sh 2" followed by a number from 1 to 313. You may have seen a few without realizing it, because some of these objects appear in other catalogs. For example, French comet-hunter Charles Messier (1730–1817) had cataloged Sh 2–25 as M8, better known as the Lagoon Nebula.

Whether you observe the Sharpless objects through an eyepiece/telescope combination or capture their faint light with sensitive cameras, this fascinating collection of objects will delight you.

ONLINE EXTRA Download the entire Sharpless Catalog at www.astronomy.com/toc.

Lighthouse *of the* skies

The U.S. Naval Observatory has blazed a path between sea and sky since its birth in the mid-19th century.

/// **BY GEOFF CHESTER**

During a visit to the United States Naval Observatory (USNO) in 1863, President Abraham Lincoln spent a few peaceful minutes observing the Moon and the bright orange glow of Arcturus through the observatory's 9.6-inch refractor. If Honest Abe were to walk the halls of today's USNO, he'd recognize some of the equipment that still provides admirable service — and marvel at the rest.

Since 1830, the USNO has evolved from its original role as the Navy's Depot of Charts and Instruments — a storage and maintenance facility for navigational equipment — to its current mission as an astronomical research institution. From a two-room shed just down the street from the White House, to another facility closer to Capitol Hill, the USNO eventually expanded to its current location in the hills outside Georgetown. It now operates the USNO Master Clock — the official time reference for

ASTRONOMY: KELLIE JAEGER

the U.S. Department of Defense — from its main site in Washington, along with its "backup" Alternate Master Clock facility in Colorado Springs, Colorado.

One of the Depot of Charts and Instruments' main missions was to calibrate the fledgling Navy's navigational equipment. To assure precision and consistency of its instruments, all the vessels in the Navy's fleet needed to operate under a common time reading. Essentially, the Depot standardized timekeeping and navigation by assuring navigational celestial charts were accurate. Of course, this work demanded an acute understanding of Earth's rotation as well as the positions and movement of celestial objects.

The inherent relationship between navigation, timekeeping, and astronomy helped the Naval Depot of Charts and Instruments blossom into the Naval Observatory. In fact, the Depot's early work helped lay the foundation for today's Global Positioning System — as monitored by the USNO.

Geoff Chester *works in the U.S. Naval Observatory's public affairs office.*

Back to the beginning

The facility was founded many years before President Lincoln's visit. On December 6, 1830, the Secretary of the Navy, John Branch, wrote a letter to Lieutenant Louis M. Goldsborough, instructing him to establish a depot for the storage of all the charts and instruments in the Navy's inventory — and the aptly named Naval Depot of Charts and Instruments was born.

Goldsborough and an assistant secured a lease on a small building near the White House and began to store, repair, and calibrate the Navy's navigational instruments. Goldsborough also was charged with determining the running characteristics of all of the ships' chronometers. As timekeeping is critical for accurate navigation, the Depot staff focused on honing its timekeeping capabilities — and consequently expanded its celestial observing.

The observatory drops the ball

Beginning in 1845, the observatory initiated dropping a "time ball" at noon each day so ship captains could check the accuracy of their chronometer logs. Measuring and transmitting the accurate time had many potential applications outside the Navy, so by 1865, a telegraph sent the time signal to all of the fire-alarm bells in Washington. In 1871, Western Union started transmitting the USNO time throughout the country, thus providing the exact time to the railroads.

As technology became more and more sophisticated, so did the USNO's renowned timekeeping abilities. New instruments regulated the movements of more precise mechanical clocks. By the 1920s, the Time Service Department's Shortt free-pendulum clocks could maintain a timescale precise to better than 10 seconds per year, the limit at which astronomers were able to determine Earth's rotation visually.

However, increasing demand for precise time required better clocks and reference systems. By the mid-1950s, physicists had developed the first clocks based on the natural resonance of the hyperfine energy transition in cesium-133 atoms. Extensive research at the USNO linked this resonance to various astronomically defined timescales. In 1967, the 13th General Confer-

BEFORE MOVING to the "rural" surroundings of Georgetown, the USNO operated in Washington's Foggy Bottom district from 1830–1844. Unfortunately, Foggy Bottom was not a particularly good site for astronomy. USNO LIBRARY

A VISIT to the U.S. Naval Observatory headquarters northwest of Georgetown allows you to walk the history of time, literally. GEOFF CHESTER (USNO)

IN 1845, by order of Secretary of the Navy John Y. Mason, the USNO dropped the first "time ball" to mark correct time for the city of Washington and ships passing by on the Potomac. In 2000, Secretary of the Navy Richard Danzig ordered the dropping of the time ball to usher in the new millennium. GEOFF CHESTER (USNO)

ence on Weights and Measures defined the International System (SI) unit of time, the second, in terms of atomic time rather than with reference to Earth's rotation.

Today, the USNO operates 75 atomic clocks at its Washington headquarters and another 15 at its Alternate Master Clock facility near Colorado Springs, Colorado. Together, these instruments produce a uniform timescale that varies by less than a nanosecond (one billionth of a second) per day. Today's electronic navigation systems and digital data-communication networks demand such extreme precision. The Global Positioning System receiver in your "go-to" telescope, your cell phone, and the Internet wouldn't work without the USNO's master clock.

The depot moves out

For most of its history, the observatory has conducted its observations from the heart of the nation's Capitol district, close to the authorities who depend on its work. From a humble two-room shed a few blocks from the White House in 1830, the facility moved to a site closer to Capitol Hill, where it remained for nearly 10 years.

In 1842, when the agency lost the Capitol Hill location, the Navy acquired a site for the Depot, and planned to furnish it with the day's best available instruments. Congress appropriated $25,000 to construct a masonry building equipped with transit instruments and a 9.6-inch Merz equatorial refractor. The funds covered the construction of a library as well as a residence for the observatory's superintendent.

A site in Washington's "Foggy Bottom" district was chosen more for its visibility from the city and surrounding waterways than for its astronomical promise. The new Depot's construction was completed in 1844, and Lt. Matthew Fontaine Maury was chosen to be superintendent.

Under the new superintendent's leadership, the Depot began to issue annual navigational and astronomical almanacs, and Maury's *Wind and Current Charts* series became the definitive source for hydrographic information for decades. In 1854, as a result of this expanded responsibility, the Depot of Charts and Instruments was renamed the U.S. Naval Observatory and Hydrographical Office.

Maury remained superintendent until April 1861. As the nation fractured prior to the Civil War, he swore his allegiance to his

USNO LIBRARY

THE 9.6-INCH Merz equatorial refractor was part of the $25,000 Congress appropriated in 1842 for the construction of a new site for the USNO. President Abraham Lincoln observed the Moon and Arcturus through this telescope in 1863.

USNO LIBRARY

The USNO 1825-1980

1825
President John Quincy Adams promotes the idea of a "lighthouse of the skies" during an address to Congress.

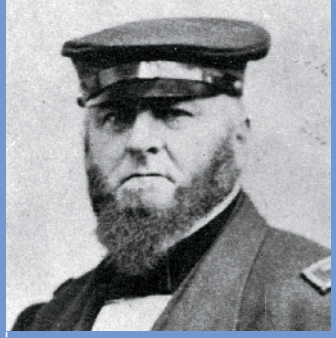
1830
Lt. Louis M. Goldsborough told to create a depot to store and maintain naval charts and instruments.

1842
Congress appropriates $25,000 to establish and equip a new facility.

1844
Permanent site established at Foggy Bottom district in Washington.

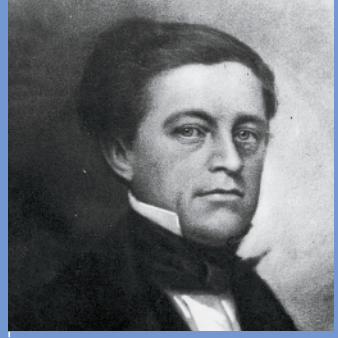
1845
Time ball installed, which is dropped every day except Sunday at local Mean Solar Noon.

1852
The American Ephemeris and Nautical Almanac *annual publication begun with data for 1855.*

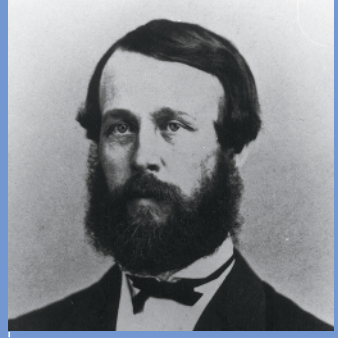


LOUIS M. GOLDSBOROUGH established a depot, or storage facility, near the White House for the Navy's complete inventory of navigational charts and instruments.

MATTHEW FONTAINE MAURY, the USNO's first superintendent, left a legacy including the annual publications *The Astronomical Almanac* and *The Nautical Almanac*.



JAMES GILLISS helped move the USNO from Capitol Hill to the Foggy Bottom district. But Gilliss had to wait nearly 20 years before being appointed superintendent.



ASAPH HALL (1829–1907) discovered Mars' rugged, tiny moons, Phobos and Deimos, in 1877 with the help of a USNO telescope, the 26-inch Great Equatorial refractor.

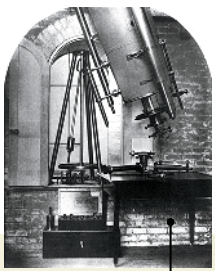
ALL 4 IMAGES USNO LIBRARY

WHEN INSTALLED in 1873, the 26-inch Great Equatorial refractor was the world's largest such telescope. In 1877, astronomer Asaph Hall discovered Mars' moons, Phobos and Deimos, through the Great Equatorial. USNO LIBRARY

USNO ASTRONOMERS continue to put the Great Equatorial to good use. Still at the Georgetown campus, the 26-inch refractor helps astronomers determine the orbital motions and masses of double stars. GEOFF CHESTER (USNO)

native state of Virginia and resigned his commission in the U.S. Navy. James Gilliss, who had served as Maury's able second-in-command for 19 years, became the new superintendent. Immediately, he was swamped with work as the Federal Navy rapidly built new ships to blockade Confederate ports. The observatory found itself rating and calibrating 3 times as many chronometers and instruments as it did before the war. The work severely stressed Superintendent Gilliss, who died of a stroke just before the war ended.

The period following the Civil War saw a growth of science and technology rooted in the reconstruction of a devastated nation. During this time, the observatory fared well under the stewardship of three superintendents: Rear Admiral Charles Henry Davis (1865–1867 and 1874–1877) was one of the founders of the National Academy of Sciences. Rear Admiral Benjamin F. Sands (1867–1874) oversaw the installation of the $50,000 26-inch "Great Equatorial" refractor — at the time, the world's largest refractor. Rear Admiral John Rodgers Jr. (1877–1882) passionately defended the work of his astronomers to his superiors, a job made easier when Asaph Hall discovered Mars' moons — Phobos and Deimos — through the Great Equatorial in 1877.



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Despite the observatory's momentum of success, the facility's scientific programs and staff both suffered from its proximity to the expanding capital city. When Foggy Bottom was first occupied in 1844, the natural mists from surrounding swampland hindered the astronomers' work.

By the 1880s, the dark clouds of smoke and soot belching from a coal-and-gas burning facility only a quarter-mile north of the observatory further obscured the observatory's view of the sky. The 1882 annual report by Rodgers indicated only 19 nights were suitable for using the Great Equatorial to its full capabilities.

The only solution to the problem would be relocating the observatory to a new, darker site away from the growing city.

1861
Lt. Matthew Fontaine Maury leaves the Navy to join the Confederate Navy; Lt. James Gilliss replaces Maury as Superintendent.

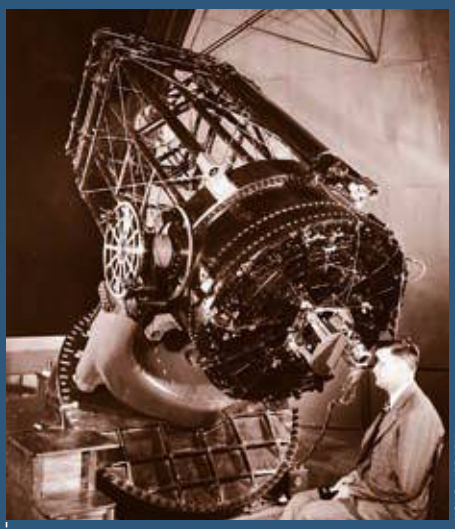
1863
President Abraham Lincoln observes the Moon and the star Arcturus through the 9.6-inch refractor with Asaph Hall.

1865
Noon signal sent by telegraph to all fire-alarm bells in Washington.

1871
Western Union transmits USNO time throughout the country, providing accurate time to the railroads.

1873
$50,000 appropriated to build 26-inch Great Equatorial at the Foggy Bottom site.

1877
Asaph Hall discovers Mars' moons Phobos and Deimos with the 26-inch Great Equatorial.

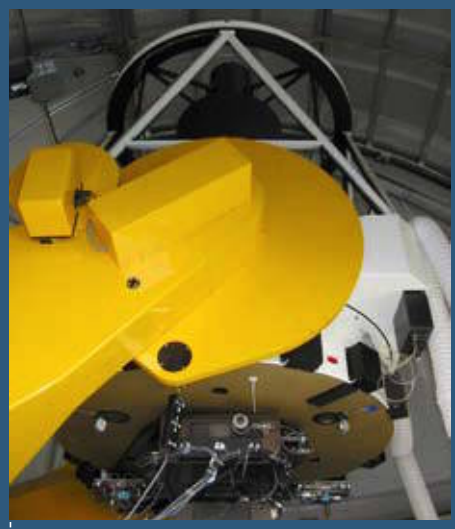


USNO LIBRARY

JOHN HALL, no relation to Asaph, got as much as he could out of the 40-inch Ritchey-Chrétien at the Georgetown facility. The telescope was later moved to a dark site in Flagstaff, Arizona.

GEOFF CHESTER (USNO)

THE 61-INCH astrometric reflector lets astronomers measure the distance, brightness, and color of stars. The instrument helped James Christy discover Pluto's largest moon, Charon.



GEOFF CHESTER (USNO)

THE USNO'S newest telescope is the 1.3-meter instrument at the Flagstaff Station in Arizona. Its modified Ritchey-Chrétien design produces a field of view in the sky of 1.3° in diameter.

Skies are always clearer

In 1881, Congress purchased 85 acres in the hills north of Georgetown for the observatory's new home. Unfortunately, due to funding issues and arguments over administrative control of the institution, the move was not completed for another 12 years.

USNO's less urban new home provided the darker skies the observatory needed for its telescopes, while still retaining proximity to the Navy command. Thanks to renowned American architect Richard Morris Hunt, the new observatory buildings and landscaping blended perfectly into their rustic surroundings.

USNO astronomers at last could enjoy dark skies and an attractive work environment. It was, in its day, an isolated place, and most of the senior naval and scientific staff resided with their families on the grounds. Observatory staff assumed Rock Creek provided a natural barrier to the east that could prevent the expanding city from encroaching upon the surrounding wooded hills and valleys. Yet, expand it did. The area around the observatory became a residential neighborhood and a commercial thoroughfare for growing Washington suburbs. Inevitably, progress changed the environment, as gaslights lit dust clouds raised by horse-drawn buggies and wagons. Then, electric lights brightened the macadam streets laid down for smoke-belching automobiles. The once-steady atmosphere began to waver in the heat generated by sunlight falling on pavement and the dark roofs of the buildings around Observatory Circle.

As early as 1927, the need for improved telescopes — and appropriate dark-sky locations for them — was discussed. The 40-inch Ritchey-Chrétien telescope, built by George Willis Ritchey and installed in 1934, was the first major instrument to be erected on Observatory Circle in 40 years. The telescope enjoyed limited success in Washington, but astronomer John Hall used it to discover the interstellar polarization of starlight. Hall realized the instrument would fare much better at a dark-sky location, and so, in 1950, he and colleague Alfred Mikesell began searching.

They settled on a 7,600-foot (2,300 meters) hilltop 5 miles (8 kilometers) west of Flagstaff, Arizona. In 1955, with the

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GEOFF CHESTER (USNO)

GEOFF CHESTER (USNO)

TRANSIT CIRCLES record the meridian transits of astronomical bodies at different declinations in the sky. When used with chronometers, these instruments helped Louis Goldsborough rate all the clocks in the Navy's inventory.

1881
Land purchased for the planned new headquarters for the USNO.

1893
USNO completes its move to its new home north of Georgetown.

1904
Naval radio station broadcasts first radio time signal.

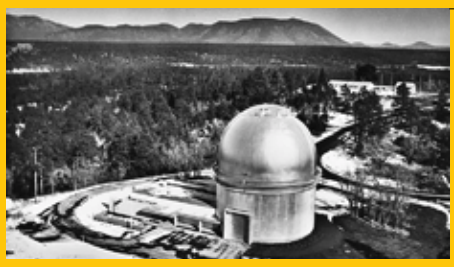
1935
40-inch Ritchey-Chrétien telescope, made by G. W. Ritchey, installed and used by John Hall to discover polarization of starlight.

1950s
The USNO and Britain's National Physics Laboratory develop first clocks based on the natural resonance of the hyperfine energy transition in atoms of cesium-133.

1955
40-inch Ritchey-Chrétien telescope moved to second USNO facility, in Flagstaff, Arizona.

GEOFF CHESTER (USNO)

THE FLAGSTAFF STATION in Arizona operates as the dark-sky site for the USNO's optical and near-infrared astronomy. There, astronomers conduct research and observations to improve the accuracy of astronomical data needed by the Navy and other components of the Department of Defense.



THE ADDITION of the Flagstaff Station in 1955 provided USNO astronomers all the dark skies they needed. This was a far cry from the mere 19 nights in a year Admiral John Rodgers reported suitable for using the Great Equatorial refractor at the Foggy Bottom observing site outside Washington.

USNO LIBRARY

40-inch moved to the site, observatory astronomers unleashed its true potential. Under Arizona's favorable skies, the telescope soon produced high-quality photometric, spectroscopic, and photographic data. The Flagstaff Station helped add astrophysical research to USNO's work in astrometry and timekeeping.

By their powers combined

In 1964, a 61-inch astrometric reflector — still the largest of its type in the world — joined the 40-inch in Flagstaff. In 1978, James Christy discovered Pluto's largest moon, Charon, after measuring photographic plates taken during a series of astrometric observations. The 61-inch reflector in Flagstaff was used to conduct the observations, and Christy studied the plates at USNO's Washington headquarters. He noticed a bulge appeared periodically on one side of Pluto's highly magnified image. That bulge turned out to be Charon.

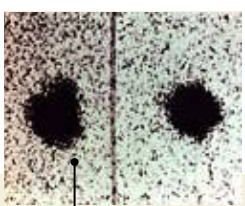
Shortly thereafter, observations with the 61-inch telescope contributed to the successful navigation of Voyager 2 through the uranian and neptunian satellite systems. In 1980, a prototype of one of the Hubble Space Telescope's charge-coupled device (CCD) cameras helped astronomers Dan Pascu and Ken Seidelmann discover Calypso, a new moon of Saturn.

Today, the Flagstaff Station provides most of USNO's visual observations. In the modern age of CCDs, USNO astronomers find new applications for the observatory's classic telescopes.

For example, astronomers using a 1970s-vintage 8-inch astrograph recently completed an observing program at Flagstaff and Cerro Tololo, Chile, to compile the most complete star catalog, with pole-to-pole coverage of more than 70 million stars down to 16th magnitude. The USNO *CCD Astrograph Catalog* (UCAC) is due to be completed in 2007.

Also at the Flagstaff Station, a new 1.3-meter telescope, tuned to observe in the infrared portion of the spectrum, measures the parallaxes and proper motions of extremely faint red- and brown-dwarf stars.

A few miles out of town, at Lowell Observatory's Anderson Mesa Station, the Navy Prototype Optical Interferometer (NPOI) successfully combined optical beams from six telescopes spanning a 100-meter baseline to obtain ultra-precise astrometry of close binary-star systems.



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Back in Washington, astronomers use the venerable 26-inch Great Equatorial to observe binary-star systems every clear night. Using a technique called "speckle interferometry," astronomers measure the separation and position angles of binary systems in minutes, as opposed to the hours previously needed with visual wire micrometers. Today the *Washington Double Star Catalog* is the definitive authority in this field, with nearly 3,000 entries added each year. The Great Equatorial is the oldest continuously operating piece of hardware in the Navy's inventory — well worth the initial $50,000 investment made by Admiral Sands in 1873.

Most visitors to USNO marvel at its stately buildings and park-like grounds set in the middle of a bustling city. Few realize some of the most exacting scientific work in the world is carried out there on a daily basis. Honest Abe would be pleased.

ONLINE EXTRA To learn more about current and future USNO astronomical projects, visit www.astronomy.com/toc.

1962
61-inch astrometric reflector installed at the Flagstaff station.

1967
The second is redefined in terms of atomic time rather than by Earth's motion.

1972
The world adopts an International Atomic Time standard.

1974
U.S. Congress designates the USNO campus as the "Temporary Official Residence of the Vice President of the United States."

1978
James Christy discovers Pluto's largest moon, Charon, using photographs taken with the 61-inch reflector.

1980
USNO astronomers Dan Pascu and Ken Seidelmann discover the saturnian moon Calypso.

1980
NAVSTAR Global Positioning System (GPS) timescale established; USNO designated as reference timescale for GPS operations.

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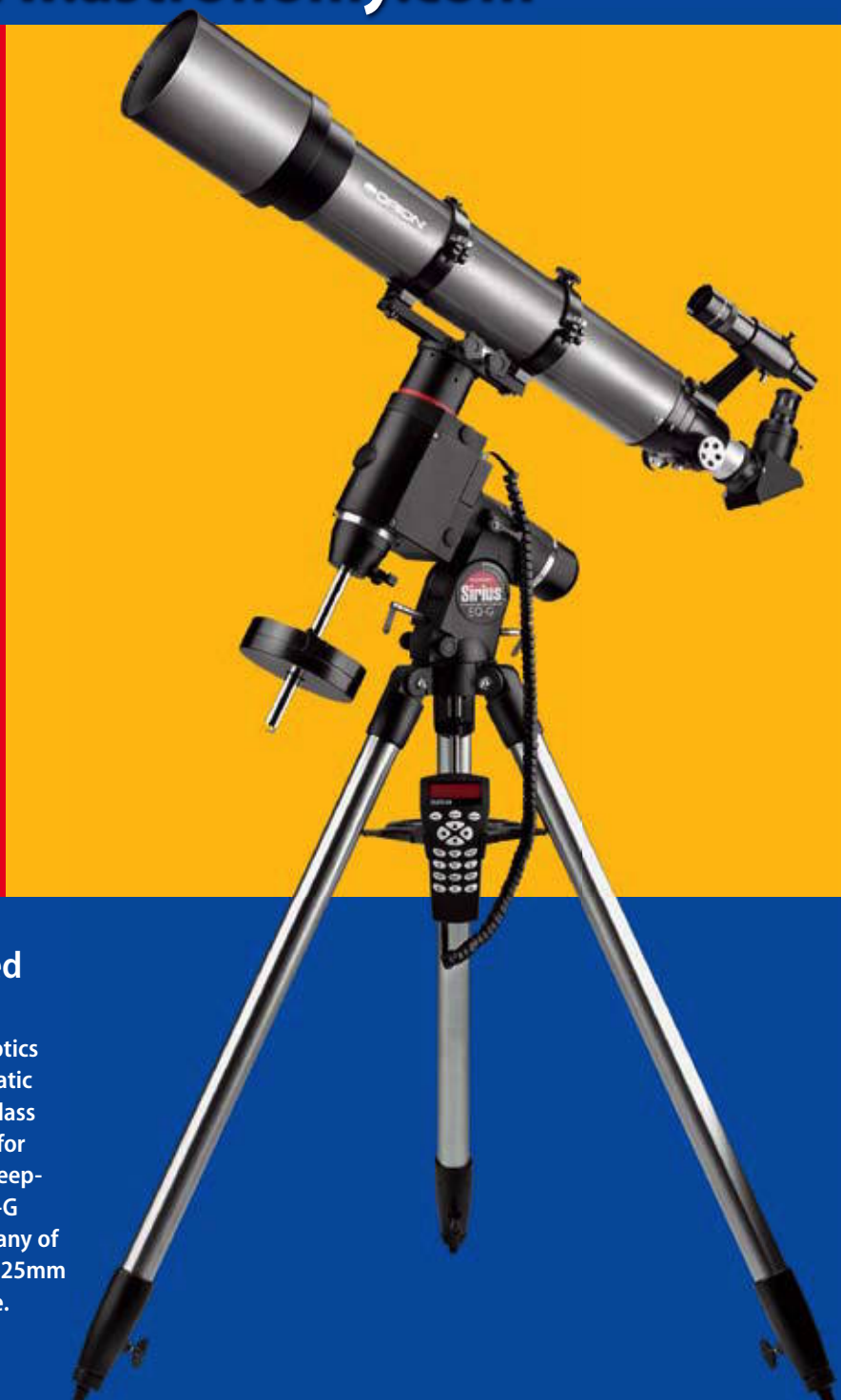

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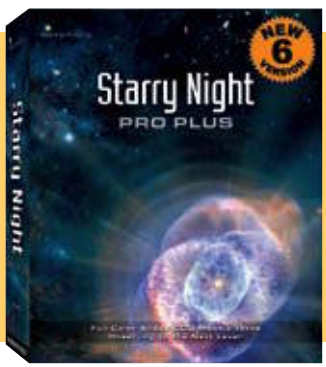

THIRD PRIZE - One Awarded

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1. No Purchase Necessary. Official entry forms are bound in the June 2007, July 2007, and August 2007 issues of Astronomy. The *Astronomy* 2007 Summer Sweepstakes is open to residents of the United States and Canada (except Quebec) only, 18 years of age or older. Employees (and their dependents and immediate household members) of Kalmbach Publishing Co., their advertising and promotional agencies and sponsoring companies are not eligible to participate.

2. Sweepstakes Entry. To enter, complete and mail the official entry form or a postcard with name, address, city, state or province, and zip or postal code to: The Astronomy 2007 Summer Sweepstakes, P.O. Box 1199, Waukesha, WI 53187-1199. Or enter online by filling in the Online Entry Form and hitting the SUBMIT ENTRY key. The Online Entry Form must be filled out completely to be eligible. Incomplete or defaced entry forms are void. One entry per household. The official ending date for The Astronomy 2007 Summer Sweepstakes will be August 20, 2007, and all entries must be transmitted or postmarked no later than that date.

3. Prizes and Odds of Winning. One drawing will be held on or around October 19, 2007 for the following awards: One (1) Grand Prize consisting of a Sirius 120ED EQ-G GoTo Apo Refractor (retail value $3,099.95). One (1) First Prize consisting of a SkyQuest XT8 IntelliScope with Computerized Object Locator (retail value $619.95). One (1) Second Prize consisting of a *Starry Night Pro Plus 6.0* (retail value $249.95). One (1) Third Prize consisting of a StarShoot Solar System Color Imager II (retail value $179.95). Ten (10) Fourth Prizes each consisting of a one-year subscription to *Astronomy* magazine (retail value $42.95 each). Fifteen (15) Fifth Prizes each consisting of a copy of *Astronomy* magazine's special issue, Atlas of the Stars (retail value $12.95 each). Cash equivalents of merchandise will not be awarded. Substituting prizes is not allowed. Any applicable federal, state, and/or local taxes are the responsibility of the winner. Odds of winning depend on the number of entries received. Total circulation for Astronomy is 131,288. Sweepstakes void in Quebec and void where prohibited.

4. Validation and Acceptance. Winners in the *Astronomy* 2007 Summer Sweepstakes will be selected in a random drawing. Canadian prize awards subject to skill test requirement. By entering the sweepstakes, participants agree to be bound by these official rules and all decisions of Kalmbach Publishing Company. Sweepstakes entries void if not legible, not completed in full, not obtained legitimately, or if forged, photocopied, mechanically reproduced, late or tampered with. The potential winners may have to sign and return an Affidavit of Eligibility, publicity release and Release of Liability within fourteen (14) days of notification. In the event of non-compliance, alternate winners will be randomly drawn. No responsibility is assumed for lost, stolen, misdirected or late entries or notifications. All sweepstakes entries become the property of Kalmbach Publishing and will not be returned.

5. Winner's List. For a list of winners, send a stamped, self-addressed envelope to: The Astronomy 2007 Summer Sweepstakes Winners List, P.O. Box 1612, Waukesha, WI 53187-1612. Residents of FL, VT, and WA may omit stamp. Requests must be received by October 19, 2007. Or check the Astronomy web site (www.astronomy.com) after October 19, 2007.

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ASK ASTRO

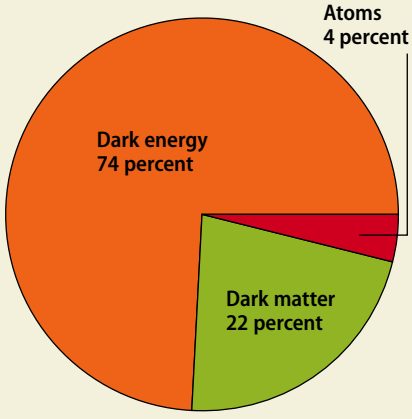
This month:
- Could black holes be the source of dark energy?
- Why do the Moon's highlands and maria reflect different amounts of sunlight?
- Expansion or explosion — what's the difference?
- Where do comet particles form?

DARK-ENERGY SOURCE

Q: Could black holes be the source of dark energy in our universe? — DAVID REDDING, LAS VEGAS

A: No. Black holes are predicted to behave somewhat like dark matter. Scientists thought previously that the dark matter in the universe might be lots of invisible black holes. The recent observations of how dark matter organizes itself into structures, such as galaxies and clusters, tend to suggest the idea is wrong.

Cosmic constituents



DARK ENERGY is much more prevalent in the universe than either dark matter or ordinary matter like planets and stars. Cosmologists don't believe quantum black holes are the source of dark energy because of a difference in timescales. Dark energy took roughly 10 billion years to become the dominant stuff in the universe, while quantum black holes have timescales lasting significantly less than 1 second.

Two of the greatest mysteries in theoretical physics are dark energy — a mysterious accelerating force in the universe — and the gravitational nature of quantum mechanics. This second mystery is essentially the question of what a black hole looks like when it is small enough to be subject to the laws of quantum mechanics.

Dark energy has a timescale associated with it: roughly 10 billion years, or the time it has taken to become the dominant component of the universe. And quantum black holes have a rough timescale as well: 10^{-44} seconds (a 1 divided by a 1 followed by 44 zeros.) It's very small, because quantum black holes must be very small.

These timescales are so different that many other scientists say dark energy and black holes must have fundamentally different physics, and that there's no relation between the two.

It's not quite a war with factions and sides, of course. But I hope I've given a good picture of why the debate is not soon to be resolved! — **SIMON DEDEO,** FELLOW OF THE KAVLI INSTITUTE FOR COSMOLOGICAL PHYSICS, UNIVERSITY OF CHICAGO

MOON'S ALBEDO

Q: What causes the difference in the amount of sunlight reflected to Earth by the Moon's highlands and maria? — RALPH CIASULLO, BRADENTON, FLORIDA

A: The highlands appear brighter, and reflect more sunlight, because they have less iron than do the maria.

The albedo (reflectance) of the highlands is between 11 and 18 percent, while the maria reflect between 7 and 10 percent of incident sunlight, so the Moon is actually a very poor mirror. The lunar highlands comprise rocks rich in plagioclase, an aluminum- and calcium-rich mineral. In contrast, the dark maria are made of basalt, a lava rich in iron and magnesium. Highland soils typically contain between 4 and 8 percent of their weight in iron, while those of the maria have between 15 and 20 percent iron content by weight.

Millions of micrometeoroids — extremely small, fast-moving meteoroids — create the dust that covers the Moon. These impacts mostly grind the surface rocks into dust, but a fraction of the dust is fused into shock melt, forming glass.

The longer a surface is exposed to space, the more of these tiny, impact-melt glasses are created. Over time, this darkens the Moon's surface. Impact glasses forming in the mare regolith — a loose layer of unconsolidated material that covers solid rock beneath — have much more iron than those in the highlands and, hence, are darker. Multiplied by billions, these glasses make the maria appear darker than the highlands. — **PAUL D. SPUDIS,** APPLIED PHYSICS LABORATORY, LUNAR AND PLANETARY INSTITUTE, HOUSTON

EXPANSION OR EXPLOSION

Q: What is the difference between the expansion of space and time following the Big Bang and matter expanding from an infinitely dense point? — ROBBY HAMILTON, PORTLAND, OREGON

A: The words "Big Bang" don't adequately describe the expansion of the universe, which is different than an explosion from a given point in space. **In an explosion, an observer sitting far from the center would see material traveling toward her.**

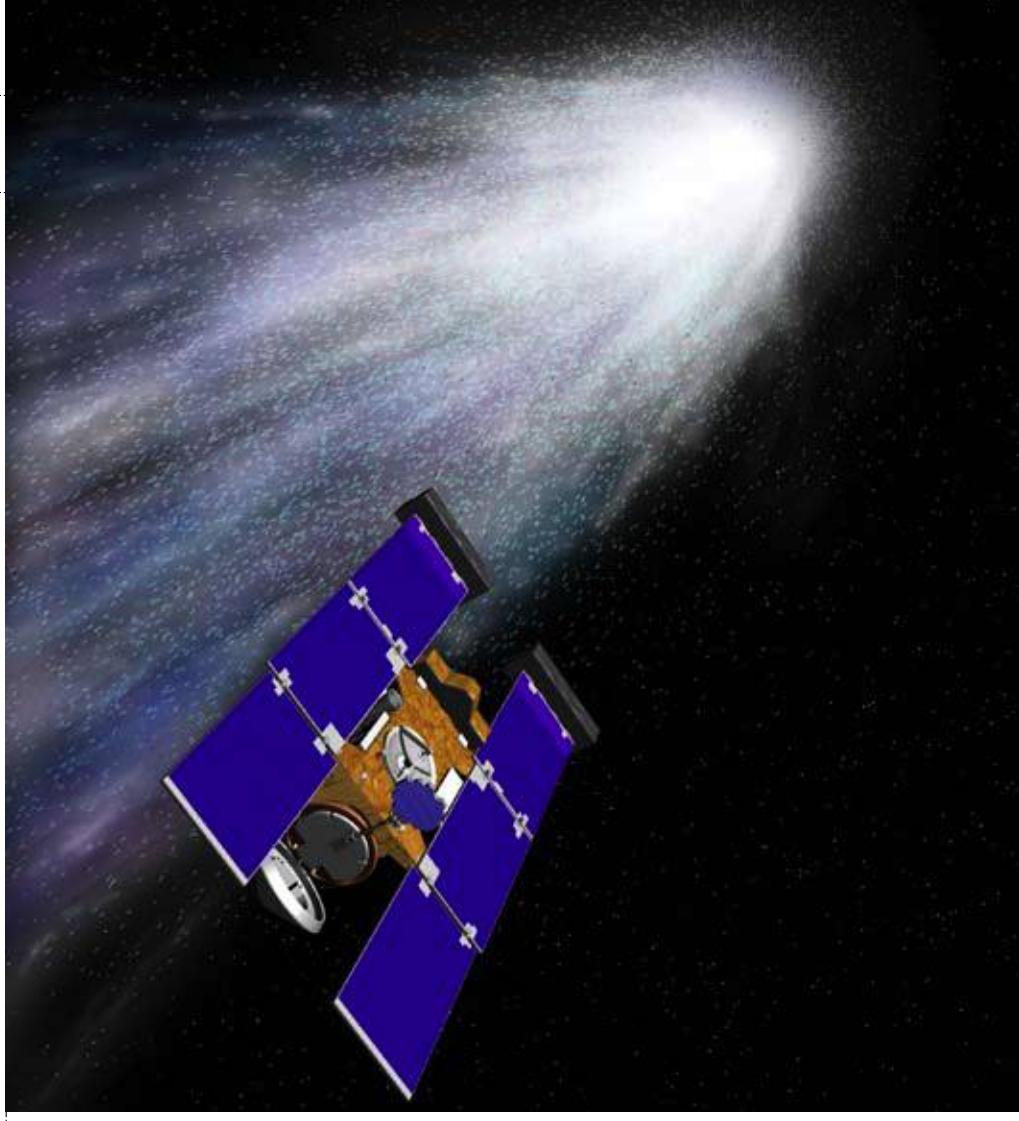
In the expanding universe, an observer at any point in the universe sees matter traveling away from her. Space itself is expanding, and all distances are getting larger. So, the expanding universe is really nothing like an explosion.

Density was also much larger earlier in the universe than it is today. This was the case everywhere, not just at one point. Again, this is quite different from an explosion, in which the density everywhere initially is very low, except at the center, and matter gets more diffuse as it travels outward. — **SCOTT DODELSON,** CENTER FOR PARTICLE ASTROPHYSICS AT FERMI NATIONAL ACCELERATOR LABORATORY, BATAVIA, ILLINOIS, AND THE UNIVERSITY OF CHICAGO

COMET ORIGINS

Q: Could particles of Comet Wild 2, collected and returned to Earth by the Stardust probe, have been picked up in the outer solar system after the comet formed? — PADRAIC SHAW, TUCSON, ARIZONA

A: The Stardust probe's target, Comet Wild 2, is a "fresh comet." It was perturbed into its present orbit, which takes it into the inner solar system, by a close encounter with Jupiter in 1974. **Prior to 1974, calculations indicate, Wild 2 orbited much farther from the Sun. So, Wild 2 has had very little time to accumulate inner-solar-system dust on its surface.**



THE STARDUST PROBE, launched February 7, 1999, encounters Comet Wild 2 (81P/Wild) in this artist's concept. Stardust collected particles from the comet's tail and returned them to Earth January 15, 2006. NASA

Also, photographs taken by the Stardust spacecraft during the January 2004 encounter with Wild 2 showed at least 20 collimated "jets" of particles and gas streaming away from the comet. These jets are believed to originate from pressurized pockets of gas and dust in the comet's interior.

Although the ratio of dust particles from the surface to those from the interior cannot be precisely determined, particles emitted from the interior in these jets appear to dominate significantly over particles released from Wild 2's surface.

The Stardust Mineralogy/Petrology preliminary examination team studied particles from 26 Wild 2 tracks in the aerogel collectors. Eighteen of these particles contained mostly olivine or pyroxene, both minerals believed to form in hot environments. Thus, although it is not possible to determine if any single particle came from the interior or from the surface of Wild 2, the presence of olivine or pyroxene in a large majority of the particles studied indicates these minerals are present in Wild 2's interior. — **GEORGE FLYNN,** STARDUST SCIENCE TEAM AND STATE UNIVERSITY OF NEW YORK, PLATTSBURGH

COMING NEXT MONTH ...

Would water released from a spacecraft into space boil because of the low pressure or freeze because of the low temperature? Post your comments about this question online at www.astronomy.com/forums.

Send your questions via e-mail to: askastro@astronomy.com; or write to: Ask Astro, P. O. Box 1612, Waukesha, WI 53187.
Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

IN THE KNOW

"FRESH" COMET
A comet that recently entered the inner solar system.

AEROGEL
A sponge-like, silicon-based solid that is 99.8 percent empty space and 1,000 times less dense than glass; used to capture comet particles.

QUANTUM BLACK HOLE
A black hole for which quantum effects — those happening on microscopic timescales — describe the collapsing matter.

The 118-year-old Astronomical Society of the Pacific is on a mission.

/// BY ANDREW FRAKNOI

Spreading astronomy around the world

In Kona, Hawaii, a 5th-grade teacher

is back in his school one evening, showing dozens of families how to play *Moon Mission*. In Cambridge, Massachusetts, an astronomy graduate student studies a thick volume of papers from a conference in the area of her Ph.D. work. In rural Arizona, an environmental science teacher prepares to lead her first star-walk, planning activities for her visitors. And near Chicago, an amateur astronomer speaks to a civic organization about how we are discovering planets around other stars.

What do these four people have in common, besides their interest in astronomy? All are using materials produced by a 118-year-old organization called the Astronomical Society of the Pacific (ASP). The ASP is dedicated to sharing the excitement of astronomy with teachers and the public and is on the cutting edge of astronomy education and outreach.

EDWARD S. HOLDEN (1846–1914), the first director of Lick Observatory, located on Mt. Hamilton, California, founded the ASP in 1889. Holden was the first president of the ASP, serving from 1889 to 1897. SHANE ARCHIVES OF LICK OBSERVATORY

In the beginning

The ASP has members in every state and in more than 60 countries, but its name harkens back to its Pacific Coast origins. The event that triggered the ASP founding was a total solar eclipse visible just north of San Francisco on New Year's Day 1889.

Lick Observatory, on nearby Mt. Hamilton, boasted the world's largest refracting telescope. The observatory had opened the year before, but the number of professional astronomers in the area was still small.

Lick's director, Edward S. Holden — talented in public relations — had written a pamphlet telling the public how to observe the eclipse. It also explained how to photograph the event.

Just across San Francisco Bay, the pamphlet seized the imagination of teacher and amateur astronomer Charles Burckhalter (then director of Oakland's Chabot Observatory). He proposed to a group of amateur astronomers and photographers a novel expedition to the zone of totality. This turned out to be a great success, producing remarkable photos.

At a meeting of the travelers' photography group in February 1889, Holden recommended they make their cooperation permanent. He suggested they form an organization that would unite professional and amateur astronomers — the Astronomical Society of the Pacific. The aim of the new society was twofold: to advance the science of astronomy and to disseminate the results of astronomical research to teachers and the public.

CHABOT OBSERVATORY ARCHIVES

CHARLES BURCKHALTER (1849–1923), the director of Chabot Observatory in Oakland, California, was instrumental in bringing together Holden and the group of amateur astronomers and photographers who would help found the ASP.

Because nothing like the society previously existed in the United States, news spread quickly and membership began to grow. The society outgrew its provincial name, but by then the weight of tradition was too strong. Also, in the first half of the 20th century, much of the work of observational astronomy took place at Pacific Coast observatories — Lick Observatory, Mount Wilson Observatory, and Mount Palomar Observatory in California, and Dominion Observatory in British Columbia. For decades, the word "Pacific" denoted a spirit of discovery even to members continents away.

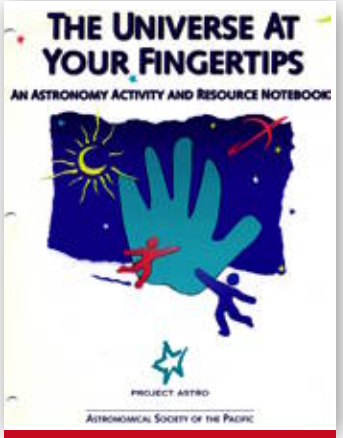
Andrew Fraknoi *was the executive director of the ASP from 1978 to 1992 and still helps with some of the programs described in this article.*

ASP leadership

At first, the society was run entirely by volunteers. Elected officers did all of the work, including monitoring membership and making sure issues of the *Publications of the ASP* went out regularly.

Many noted astronomers took on long-term ASP leadership roles. For example, amateur astronomer and business executive Charles H. Adams served as secretary of the ASP from 1925 to 1950, keeping membership records in his home. His son, who remembered seeing ASP materials on his kitchen table as he was growing up, inherited his father's interest in both astronomy and photography. You may recognize the son's name — Ansel Adams — more readily than the father's. Adams' images broke new ground in nature photography.

World-renowned astronomers such as Edwin Hubble, Harlow Shapley, Carl Sagan, and Clyde Tombaugh first wrote up their work in the journal or leaflets of the ASP. And some of the pioneers of 20th-century astronomy gave public talks at ASP meetings and lecture series. Many also served on the society's board of directors, including Maarten Schmidt, the discoverer of quasars, Frank Drake, the father of the Search for Extraterrestrial Intelligence (SETI) science, and Bart Bok, a pioneer in our understanding of star birth and the Milky Way.


THE UNIVERSE AT YOUR FINGERTIPS
AN ASTRONOMY ACTIVITY AND RESOURCE NOTEBOOK
PROJECT ASTRO
ASTRONOMICAL SOCIETY OF THE PACIFIC

THIS 800-PAGE NOTEBOOK, *The Universe at Your Fingertips*, is one of the ASP's most popular publications. It features 90 hands-on activities and an introduction to teaching astronomy for grades 3–12. ASP ARCHIVES

Expanding programs

Eventually, however, the society's growth required paid staff to support the volunteers. The first were administrative assistants, but in 1972 the membership hired an executive officer and a major expansion of the society's outreach became possible.

In the decades that followed, the ASP introduced a host of new activities. Among them were a non-profit mail-order catalog containing innovative teaching materials, two radio programs, a syndicated newspaper column on astronomy, a national series of teacher workshops, and a newsletter for grade 3–12 teachers.

Hundreds of thousands of teachers, students, and armchair astronomers around the world have used these materials and participated in ASP programs over the years. Sometimes the demand overwhelmed the society's small staff, as happened during the 1986 passage of Halley's Comet. But local members stepped in, making donations and helping produce and mail ASP pamphlets, slide sets, resource guides, and teaching kits, sometimes thousands at a time. Today, online activities dominate, and the society has packed its web site (www.astrosociety.org) with materials for people interested in astronomy.

Outreach programs

To celebrate its 1989 centennial, the ASP undertook a fund-raising campaign to obtain a home of its own, in the city where it all started — San Francisco. The new office allows even greater expansion of the society's educational programs, aided by grants from both the National Science Foundation and NASA. Indeed, one of the society's goals was to become an international clearinghouse for astronomy educators and communicators.

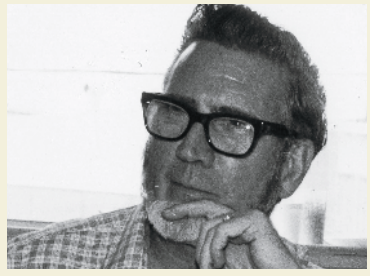
One key group is school teachers, particularly those who teach astronomy units but have no training. During previous ASP summer workshops, teachers consistently asked for an astronomer of their own to help them in the classroom. In the early 1990s, the Society initiated Project ASTRO to meet their requests. This program, now operating in 13 sites in the United States, pairs volunteer astronomers — both professionals and amateurs — with 4th- to 9th-grade teachers.

Amateur astronomers are wonderful ambassadors for astronomy in and out of the classroom. Project ASTRO trains astronomers and teachers together to lead hands-on activities about common sky phenomena. The project manual, *The Universe at Your Fingertips*, is full of opportunities for kids to learn.

Stellar leadership

JAMES STOKELY, ASP ARCHIVES

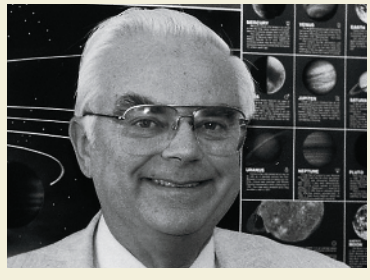
EDWIN HUBBLE (1869–1953), the father of extragalactic astronomy and the man for whom NASA named the Hubble Space Telescope, headed the ASP in 1933.


ANDREW FRAKNOI

GEORGE ABELL, who cataloged great clusters of galaxies and wrote an influential textbook for beginning astronomers, was the ASP's president from 1969 to 1971.

NOAO

SIDNEY WOLFF, director emerita of the National Optical Astronomy Observatory, was the first woman to direct a national observatory in the United States. She ran the ASP from 1985 to 1987.


ANDREW FRAKNOI

FRANK DRAKE, who pioneered the scientific search for signals from extraterrestrial civilizations, was the ASP's leader from 1989 to 1991.

A FAMILY in Hawaii plays the *Moon Mission* game produced by the ASP's Family ASTRO project. JANICE HARVEY, GEMINI OBSERVATORY

Project ASTRO training has produced more than 2,000 astronomer-teacher partnerships and has reached nearly 200,000 students over the last 13 years. In 2003, the ASP launched a new offshoot of the project, called Family ASTRO. With the help of a professional game manufacturer, the ASP created astronomy games, kits, and family nights, which can easily be led by people with a modest astronomy background.

About 600 family-event leaders have been trained and are organizing activities for families. Visit the ASP's web site (www.astrosociety.org) for information on how to get involved with Family ASTRO.

The success of amateur astronomers in these outreach projects led the ASP to team up with NASA and the Jet Propulsion Laboratory to form Night Sky Network. This program helps astronomy clubs engage in more community outreach projects and provides material and training for club members who want to share their enthusiasm. More than 200 member clubs have logged some 4,000 public events since the project began in March 2004.

A new project called Astronomy from the Ground Up targets another group — the staff of science museums, nature centers, and outdoor education sites. The program already is training staff in these institutions in hands-on astronomy using both workshops and the Internet.

Every 3 years, the society runs a national Cosmos in the Classroom symposium for about 200 instructors of beginning astronomy courses. In August 2007, this event will be held at Pomona College in Claremont, California.

THE CATHERINE WOLFE BRUCE Gold Medal, the ASP's highest honor, has been awarded for a lifetime of contributions to the science of astronomy since 1898. Winners include many of 20th-century astronomy's greatest names from around the world. ASP ARCHIVES

Other spheres

The ASP also connects with its members and audiences in other ways. It publishes a technical journal, a series of books with the proceedings of astronomical conferences, a colorful magazine for members, and a free online newsletter for teachers.

Since 1898, the ASP has presented a series of coveted awards for both research and educational activities (see "ASP awards," above). The Society also holds annual meetings that encourage everyone involved in astronomy education and outreach to come and share their work and to learn from one another.

ASP AWARDS

Besides educational, hands-on publications, the Astronomical Society of the Pacific presents the following annual awards. Visit the ASP's web site at www.astrosociety.org for information and specific eligibility requirements. — *A. F.*

The BRUCE MEDAL — the Society's highest honor — recognizes an individual's lifetime of achievement in astronomical research.

The TRUMPLER PRIZE is awarded for the outstanding Ph.D. thesis written in North America.

The MUHLMANN AWARD is presented to someone who has made important contributions to astronomical instruments, software, or observational infrastructure.

The KLUMPKE-ROBERTS PRIZE recognizes a lifetime of achievement in the popularization of astronomy.

The EMMONS AWARD celebrates outstanding work in the teaching of college-level astronomy for students who are non-science majors.

The BRENNAN AWARD is given each year for work in the high-school teaching of astronomy.

The LAS CUMBRES AMATEUR OUTREACH AWARD recognizes extraordinary work by amateur astronomers in popularizing astronomy.

The AMATEUR ACHIEVEMENT AWARD is presented for major contributions to the field of astronomy by an amateur astronomer.

Astronomy magazine partners with the ASP to assist in educating amateur astronomers as astronomy outreach facilitators. You'll find sample activities from the ASP and more on their programs online at Astronomy.com.

Astronomy can inspire people of all ages. But ASP's Executive Director Michael Bennett says the sparks of curiosity and wonder about the universe "rarely jump directly from the sky — more often they jump from one person to another."

Helping those sparks to jump has been the mission of the Astronomical Society of the Pacific for more than a century, and it welcomes everyone's help. In a world where science education is waning, few missions seem as important.

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/// BY MIKE D. REYNOLDS

Astronomy tests Celestron's CPC 1100 GPS

The Schmidt-Cassegrain telescope has come a long way since Celestron International introduced it in 1970. Celestron's original orange-tube C8 is memorable for its somewhat-radical optical and mount designs and reasonable cost. Back in the 1970s, most amateur astronomers used commercial 4- or 6-inch Newtonian reflectors or small refractors. Also, home-built telescopes abounded. But Celestron and the 8-inch C8 changed all of that.

Unpacking and setup

Celestron's CPC line of Schmidt-Cassegrain telescopes comes in three sizes: 8-inch, 9.25-inch, and 11-inch. The CPC 1100 — the 11-inch version — arrived with the tripod in one box and the telescope and accessories in a second. After unpacking, I set the tripod up first, then placed the fork-mounted telescope on it.

The heavy-duty tripod comes standard with the CPC 1100 system. The first SCT tripods could pinch a finger, or worse. But the CPC 1100 tripod is safe and easy to set up right out of the shipping carton.

The tripod's center-support bracket (and accessory tray) spreads its legs and contributes to a solid mount. This tray serves as an eyepiece holder and rotates out of the way when you fold and store the tripod.

THE TELESCOPE'S BASE covers the computer that contains the celestial database. Also, it has five external ports (hand control, two auxiliary, PC interface, and auto guider), a 12-volt input jack, the azimuth locking knob, and the on-off switch.

Solid locks adjust the tripod's height. A built-in level on top of the tripod lets you flatten the tripod's top before attaching the telescope. A level tripod is important for best operation of the CPC 1100's NexStar go-to computerized control system. The tripod also includes an attached strap that holds the legs together for storage and transport. This Celestron heavy-duty tripod rates just that: heavy duty.

After setting up the tripod, I prepared to attach the telescope and observe. As I've grown older, I've adopted the philosophy, "If it's hard to use, then I won't use it." So, I was curious to find out how difficult it would be to lift the telescope and secure it to the tripod. A handle on one fork and the instrument's balance made hefting the telescope into place easy. Personally, I would have preferred two handles.

The telescope easily centers on the tripod head with the help of a positioning pin. Rotate the telescope until you hear/feel the pin snap into place, and then tighten the three tripod screws. I had no difficulty doing this in the dark and needed no aftermarket centering product.

The CPC 1100 package includes a 1¼" star diagonal, an 8x50 finder scope, and a 40mm eyepiece. The finder was easy to install. The supplied 40mm eyepiece yields 70x — a good starting magnification for the Moon, bright planets, and deep-sky objects. If you don't have other eyepieces, you'll want to acquire additional ones.

I found the altitude and azimuth motions smooth and the clutches easy to use and engage. The controls were easy to find and use in the dark.

You must engage the CPC 1100's clutches to use the NexStar computerized

control system. The CPC 1100 obtains power either through a supplied 12-volt car-battery adapter (cigarette-lighter plug) or some other external 12-volt power source, such as an AC adapter.

At the base of the CPC, you'll find a jack to plug in the power supply, the on-off switch, and a variety of ports: one each for the NexStar hand controller, PC interface, and auto guider, and two auxiliary ports. A hand-controller holder fits onto the CPC 1100 fork arm opposite the arm with the handle; the control plugs into the base.

Planets, stars, and more

To start observing, place the telescope in one of its alignment modes. I worked with both the Auto Two-Star Align and the Solar System Align. It took only a few minutes for the receiver to acquire the GPS satellites. Once engaged, the Auto Two-Star Align worked well. The NexStar has a menu you must learn to navigate. Celestron made its go-to menu intuitive, but it still takes some getting used to.

During my last test run, I employed the Solar System Align, using a 33-percent waxing Moon and Jupiter as my two alignment objects. The go-to system worked as advertised. From Jupiter, I slewed the scope

/// SPECIFICATIONS

CELESTRON CPC 1100 GPS

Type: Schmidt-Cassegrain telescope
Diameter: 11 inches (280 millimeters)
Focal length: 2,800mm
Focal ratio: f/10
Mount: Dual-fork arm
Optical-tube construction: Aluminum
Optical-tube length: 23" (580mm)
Weight: Telescope: 65 pounds (29.5 kilograms), Tripod and mount: 19 pounds (8.6 kg)
Visual resolution: 0.5"
Limiting visual magnitude: 14.7
Optical coatings: Starbright XLT
Street price: $2,799

Contact information:
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[t] 310.328.9560
[w] www.celestron.com

CELESTRON'S CPC 1100 GPS comes with everything you need to observe right away, including a computer database containing 40,000 celestial objects.

ALL PHOTOS: *ASTRONOMY:* WILLIAM ZUBACK

THE MOUNT'S DUAL FORK ARMS are cast from aluminum. By using this material, Celestron can reduce the telescope's weight while maintaining stability. A carrying handle sits on the fork's right arm, and a detachable mount for the hand controller is on the left arm.

THE CPC 1100 GPS is an 11-inch f/10 Schmidt-Cassegrain telescope. Its focal length is 2,800 millimeters, which means the supplied 40mm eyepiece yields 70x. With this scope, you'll see stars as faint as magnitude 14.7; its theoretical resolving power is 0.42". All optics receive Celestron's Starbright coating, which increases light throughput.

over to the Ring Nebula (M57) in Lyra with good pointing accuracy.

The first celestial object I observed was a 34-percent waning Moon. Using the supplied 40mm eyepiece, the image was crisp. Seeing was excellent, so I increased the magnification to 200x with one of my own eyepieces and found the image was still sharp. I noticed no false color or other aberrations. Feeling lucky, I pushed the scope to 418x and was not disappointed.

Focus was easy to attain, and the CPC 1100's focuser worked smoothly, a major concern to me when I use a telescope at high powers. Even at 418x, the Moon's features were sharp and well defined.

I turned my attention to Jupiter. Seeing had deteriorated a bit by then, yet the image of Jupiter appeared as great as I expected. I ventured only to 200x due to the conditions. But again, I found a sharp focus and a pleasing image.

My next stops were stars. I like to look at bright stars because doing so helps me gauge a telescope's quality. I chose Vega, the beautiful blue-white zero-magnitude star in Lyra, and Antares, an orange 1st-magnitude star in Scorpius. The CPC 1100 produced nice images of both stars at 70x and 200x. The colors were true and, much like Jupiter, pleasing to my eye. Near Vega, I stopped by to visit my old friend the Double Double (Epsilon [ε] Lyrae). The scope easily split both pairs at all magnifications.

During my sky tour with the CPC 1100, I checked out several deep-sky objects. I was eager to see the Ring Nebula (M57), a wonderful planetary nebula. The Ring made a great sight at 88x. The night sky was still not at its best, so I ventured up to only a modest 200x. At this power, I found a faint — yet obvious — smoke ring.

I observed the Trifid Nebula (M20) and globular cluster M55 in Sagittarius, and M80, one of Scorpius' globular clusters. Throughout my tests, the CPC 1100's NexStar computer-control system worked accurately. Even at high magnifications, the CPC 1100 provided a steady finding and tracking device.

Two thumbs up

The Schmidt-Cassegrain telescope has come a long way since Celestron first introduced it. Many innovations — optical, mechanical, and electrical — have been developed during these years.

Celestron's latest entry, the CPC 1100 11-inch Schmidt-Cassegrain telescope, is a high-quality instrument that's easy to set up and use. The 11-inch aperture has enough light-gathering ability to give an inspiring view of the night sky. Usually, a large aperture means the scope is more difficult to set up and, for some observers, too heavy. But the CPC 1100 is easy to handle, attractive, and nicely engineered. But most important — to me, at least — is the fact that its images are superb.

THE HEAVY-DUTY TRIPOD supplied with the CPC 1100 GPS provides a stable, adjustable observing platform. The leg brace functions as a tray that holds eyepieces or accessories, and the strap keeps the legs together during transport.

Mike D. Reynolds *is the associate dean of mathematics and science at Florida Community College at Jacksonville, and the author of several astronomy books.*

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BY GLENN CHAPLE

Angular distances and colors

"The new comet will be 30 degrees above the western horizon at sunset." ☾ "Venus is 1½ degrees from the Moon tonight." ☾ In astronomy, the question "How far?" usually pertains to a cosmic object's distance. Sometimes, as in the examples above, "How far?" refers to an angular distance in degrees. Here are two quick ways to determine degrees in the night sky.

Measuring large angular separations is a hands-on activity — literally! Your hand, held out at arm's length, forms several benchmark measures. The thumb and little finger extended outward to the sides span 25°. The width of your fist measures about 10°. In that fist, your three middle fingers and little finger measure increments of about 3° and 1°, respectively.

The Moon is our yardstick for smaller angular distances. On average, its disk is a half degree across, or 30' (arcminutes). One degree equals 60'. For a rough approximation of a binoculars' field of view, determine its width in Moon diameters, then divide by two. The same procedure works as a quick way to gauge a finder scope's or eyepiece's field. Once you know a field's diameter, you can estimate the angular separation or diameter of anything it encompasses.

Think you have a handle on sky distances? Use the methods mentioned above to measure the angular distance in degrees between the Alpha and Beta stars of the following constellations (answers next month): Aquarius, Aquila, Boötes, Capricornus, Cygnus, Delphinus, Hercules, Libra, Lyra, Ophiuchus, Pegasus, and Scorpius.

Color and the eye of the beholder

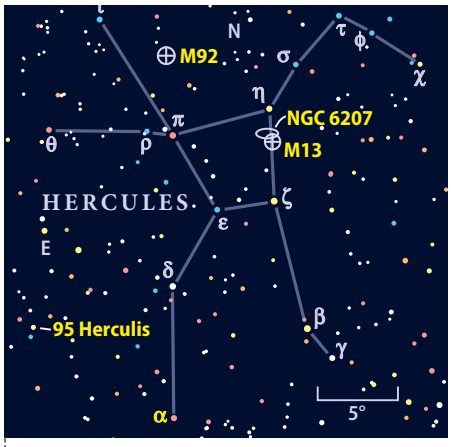
Years ago, I read the double star 95 Herculis possesses components with "apple-green and cherry-red" hues. This, I had to see! Eagerly, I aimed my 3-inch reflector at the appropriate location, peered into the eyepiece, and was disappointed to see two whitish stars. A few years later, with a more experienced eye and a 6-inch Alvan Clark refractor, I revisited 95 Herculis. Under careful scrutiny with high magnification (360x), the brighter component seemed bluish white, the partner slightly yellowish.

A year ago, I invited readers to view 95 Herculis and forward their own color impressions. Paul Soron, observing with his brother at Indian Head, Saskatchewan, studied 95 Herculis with a 60mm refractor and a magnification of 97x. Their results: "Component A: always robin-egg blue, but coloration subtle. Component B: white with the occasional tinge of orange fading in and out of visibility. Oddly, after observing this pair for a while, the colors seem to briefly switch between components! My brother viewed both components as 'grape' colored that eventually faded to a rose and then to a 'colorless' state. No difference in color or shade between components was noted."

Observing 70 miles west of Houston with a 70mm refractor at 68x, Bill Pellerin had similar results: "A quick look suggested that I observed two white stars of nearly equal magnitude. After looking for a while, I decided that there is some subtle color difference; I'll call it blue-white and amber."

These observations mirror the results of a survey on 95 Herculis I detailed in the December 1980 issue of *Deep Sky Monthly*. Nine amateur astronomers with a combined 133 years of observing experience reported similar results — a bluish-white primary accompanied by a yellowish or amber secondary. Case closed? Hardly! In April's *Astronomy*, James Mullaney included 95 Herculis in his article, "Observe the sky's most colorful double stars." What colors did he ascribe to this pair? You guessed it — "apple-green and cherry-red!" Referring to 95 Herculis, the late San Francisco amateur astronomer Herman Fast once noted, "Show 10 different people a star colored red and you'll get 10 different red-like responses." Why not check out this fascinating double star and decide for yourself?

This is the time of year when I tentatively schedule next year's "Observing basics." If you have any suggestions for beginner-friendly topics, e-mail me at gchaple@hotmail.com.



95 HERCULIS sports components of magnitudes 5.1 and 5.2, separated by a little more than 6"— a gap easily breached by the smallest telescopes. *ASTRONOMY:* ROEN KELLY

BY PHIL HARRINGTON

Time for tea

I promised last month we'd get together

for a spot of celestial tea. Of course, I'll "pour" from Sagittarius' famous asterism the Teapot. Known in ancient times as an archer, with his arrow aimed tentatively toward Scorpius immediately to the west, Sagittarius is usually portrayed as a centaur — a mythological half-man, half-horse creature.

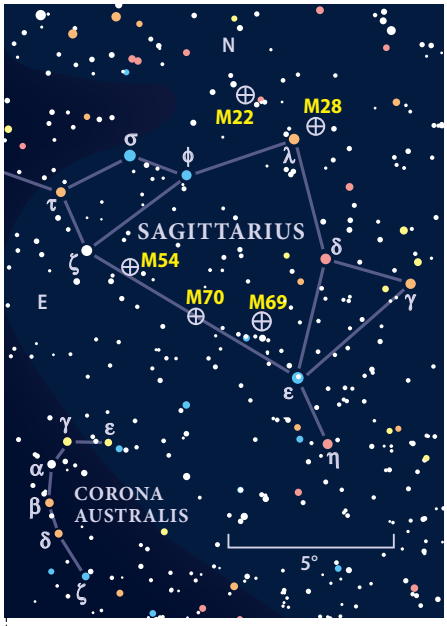
Our modern perception views eight of Sagittarius' brightest stars as a perfect teapot, complete with a lid, spout, and curved handle. And the asterism's tea is always ready, judging by all of the billowing "steam" — the Milky Way!

Using our binoculars and a little imagination, it's easy to add a teaspoon to our setting. The late astronomy writer George Lovi (1939–1993) pointed toward a triangle of faint stars northeast of the teapot's handle. Lovi suggested that by attaching two faint stars a little farther to the east, we have a perfect "teaspoon." The spoon's stars are just visible by eye under dark skies and are an easy catch with binoculars.

Continuing his imagery, Lovi suggested that the faint arc of stars south of the teapot is our slice of lemon. That's actually the dim constellation Corona Australis the Southern Crown, but it works well for this dual purpose. Again, the stars are visible by eye, but binoculars will help to trace out the full arc.

Sagittarius offers five "lumps of sugar" to observe through binoculars — five globular clusters, that is. Through telescopes, these clusters look like mounds of sugar poured onto a velvety black background. We may not be able to resolve these clusters into stars through binoculars, but their confectionary appearance reminds us of distant sugar cubes.

The sweetest globular of the bunch is **M22**. Look toward Kaus Borealis (Lambda [λ] Sagittarii) at the top of the teapot's lid, and then scan just to the east. M22 will look like a blurry, round disk next to an isosceles triangle of faint stars. Many observers, myself included, find M22 to be the finest globular visible from most of the Northern Hemisphere, outclassing even mighty M13 in Hercules.



SAGITTARIUS boasts five particular clusters that serve as "sugar" for "tea drinkers" observing with binoculars. *ASTRONOMY:* ROEN KELLY

Now, pan just to the northwest of Kaus Borealis for a second, much tougher globe of distant stars. Through binoculars, **M28** looks like a small smudge between Kaus Borealis and a dim field star. It's much harder to find than its more impressive neighbor, but take your time and M28 eventually will surrender to your hunt.

Our final three globulars lie along the bottom of the teapot, but be forewarned, they are daunting tests through binoculars. Use a pair of fainter stars east of the star Kaus Australis (Epsilon [ε] Sagittarii) as a guide. **M69** lies just to their north, while **M70** is to their east. M69 and M70 each shine at only 8th magnitude, so wait for a clear, haze-free sky before trying your luck. Under better than average conditions, I can see each as a faint, slightly fuzzy "star" through my 10x50s.

The third globular in this area, **M54**, is easiest to find by starting at Ascella (Zeta [ζ] Sagittarii), the teapot's lower-left star. M54 lies directly to its west, just south of a triangle of dim stars. Like its two compatriots, M54 will impress you as a tiny, blurry point of light highlighted by a slightly brighter center.

Messier bust

In March, Glenn Chaple and I both wrote about our "competition," but once again, weather in the northeastern United States did not cooperate on the prime weekend. For my side of the race, I was able to accomplish an impromptu midweek mini-marathon with my 10x50 binoculars, nabbing 48 Messier objects in a split session early in the evening and then later, just before sunrise. But that was anticlimactic at best. I later heard from Bill Helms in Old Town, Florida, who saw 56 objects through his 15x45 binoculars. Glenn and I hope we will have better luck with the weather next year.

Have a question or comment? E-mail it to me at phil@philharrington.net.

Next month, we visit the tiny constellation Lyra. Until then, remember that two eyes are better than one!

ONLINE EXTRA For more binocular "crumpets" to have with your celestial tea, visit www.astronomy.com/toc.

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AUGUST 9–12
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AUGUST 9–12
Indiana Family Star Party/GREATCon
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AUGUST 9–12
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River Place Park, Ayton, Ontario. 💻 www.nyaa.ca/index.php.

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AUGUST 10–12
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AUGUST 11–19
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Mt. Kobau, near Osoyoos, British Columbia. 💻 www.mksp.ca.

AUGUST 11–12
Toledo Astronomical Association Annual Star Party
Pioneer, Ohio. 💻 www.toledoastronomy.org.

AUGUST 16–19
Oregon Star Party
Ochoco National Forest, near Prineville, Oregon. 💻 www.oregonstarparty.org.

AUGUST 18
Griffith Observatory Public Star Party
Griffith Observatory, Los Angeles. 💻 www.griffithobservatory.org/pstarparties.html.

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RASCALS Star Party
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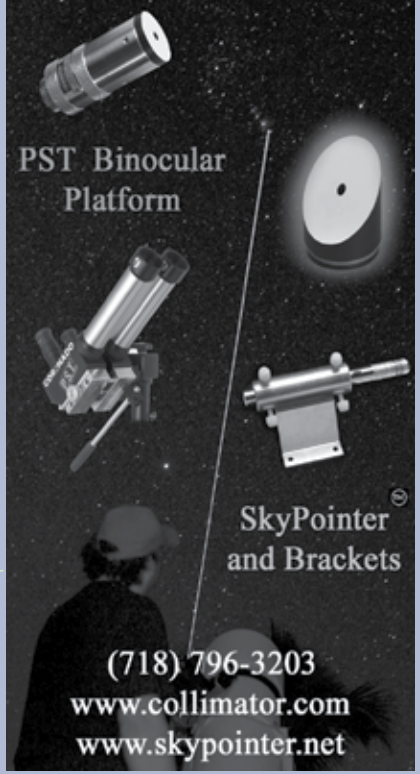

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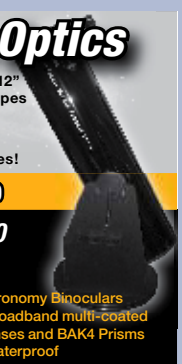

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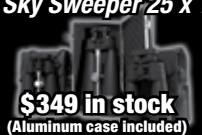

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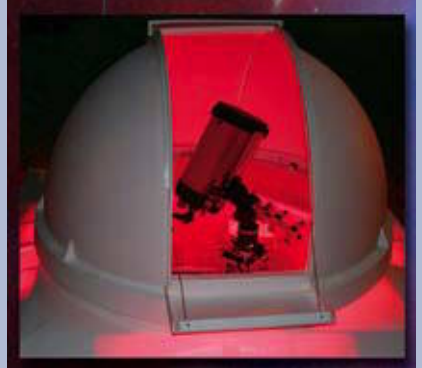

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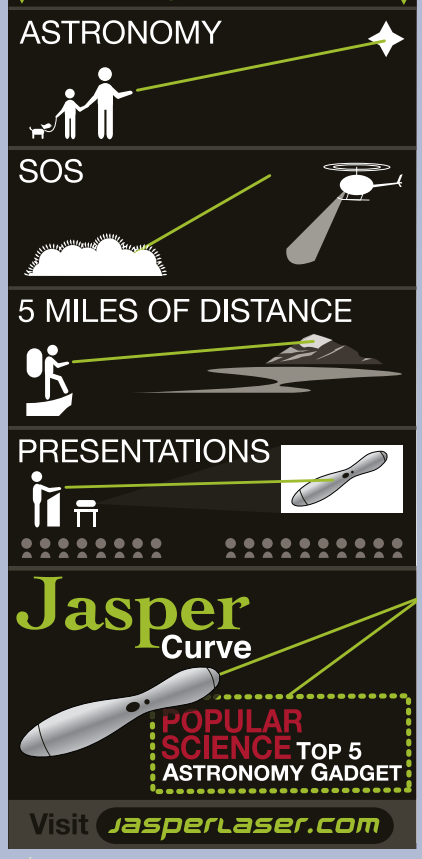

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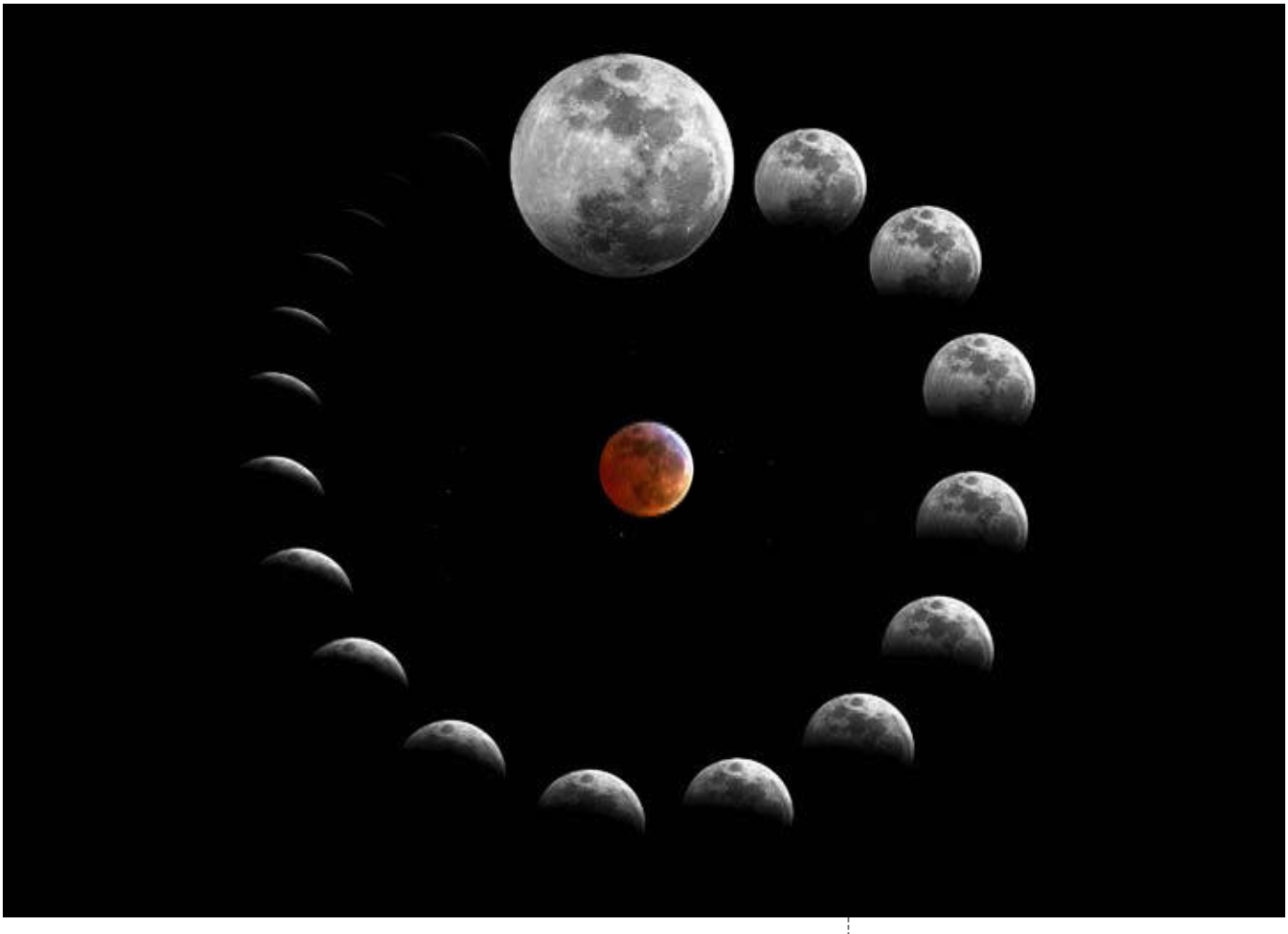


LUNAR ECLIPSE

The Moon in Earth's shadow

March 3, 2007, brought the first total lunar eclipse since October 2004. Observers in Europe and Africa found themselves perfectly positioned to view this event. North Americans didn't enjoy as good a view, but observers on the East Coast and as far west as Missouri saw at least some of the total phase. At mideclipse, when the Moon lay deepest in Earth's umbra (the darker part of its shadow), observers reported the Moon took on colors ranging from bright orange to rusty red. North and South American residents will have prime seats for the next eclipse August 28 (see page 44).

ECLIPSE SEQUENCE (3.6-inch Meade ETX-90EC Maksutov-Cassegrain telescope with a 30mm Plössl eyepiece, HP Photosmart 850 digital camera, various exposures, taken March 3, 2007, around 11:35 P.M. local time from Almada, Portugal) /// **MIGUEL CLARO, CORROIOS, PORTUGAL**

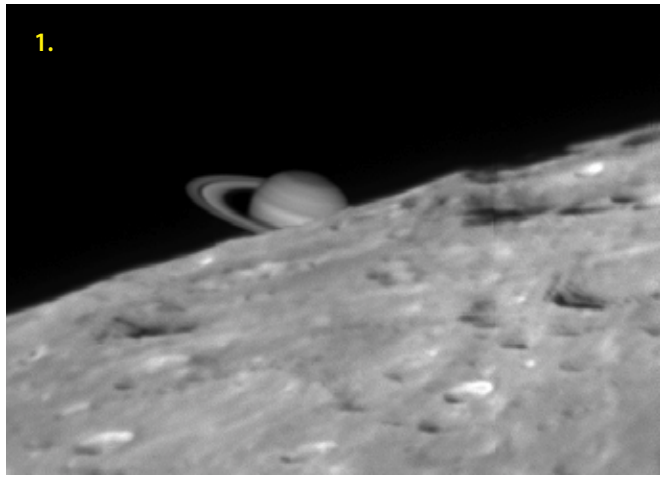
SPIRAL GALAXY NGC 1097 in Fornax lies 45 million light-years away. Just to the right of NGC 1097 sits a smaller satellite elliptical galaxy, which lies 42,000 light-years from the larger galaxy's center. The smaller galaxy gravitationally distorts NGC 1097's lower spiral arm. (20-inch [Mayhill, New Mexico] and 12-inch [near Melbourne, Australia] RC Optical Systems Ritchey-Chrétien reflectors at f/8, SBIG STL-11000 CCD camera, LRGB image, with exposures of 595, 225, 135, and 270 minutes, respectively) /// **R. JAY GABANY, SAN JOSE, CALIFORNIA**

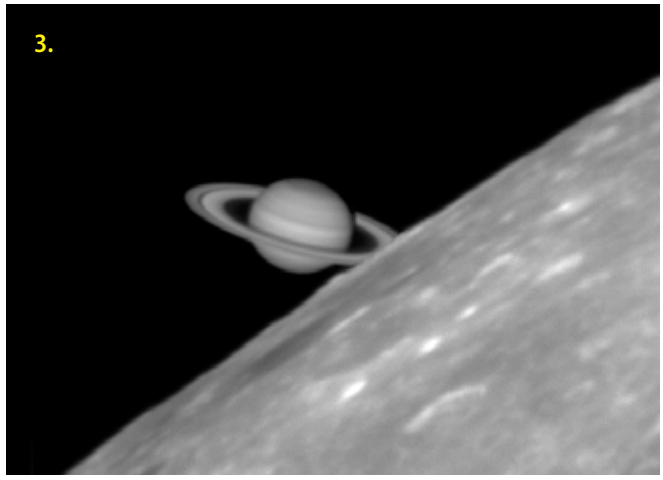
RED SHARPLESS 2–230 in Auriga dominates this image, but this region boasts many other worthy celestial targets, including magnitude 6.4 open cluster M38. (6.4-inch Takahashi Epsilon hyperbolic astrograph at f/3.3, SBIG STL-6303 CCD camera, HαRGB image, with exposures of 240, 30, 30, and 30 minutes, respectively) /// **DEAN SALMAN, TUCSON, ARIZONA**

Send your images to: *ASTRONOMY* Reader gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of image and complete photo data: telescope, camera, and exposure information. To submit images electronically, visit www.contribute.kalmbach.com.

SPIRAL GALAXY NGC 1313 in Reticulum shows star-forming regions, seen here as blue patches. NGC 1313 lies only 15 million light-years away, close enough for large telescopes to resolve individual stars in it. (14.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG STL-11000M CCD camera, LRGB image with exposures of 160, 80, 80, and 80 minutes, respectively) /// **DANIEL VERSCHATSE, ANTILHUE OBSERVATORY, CHILE**

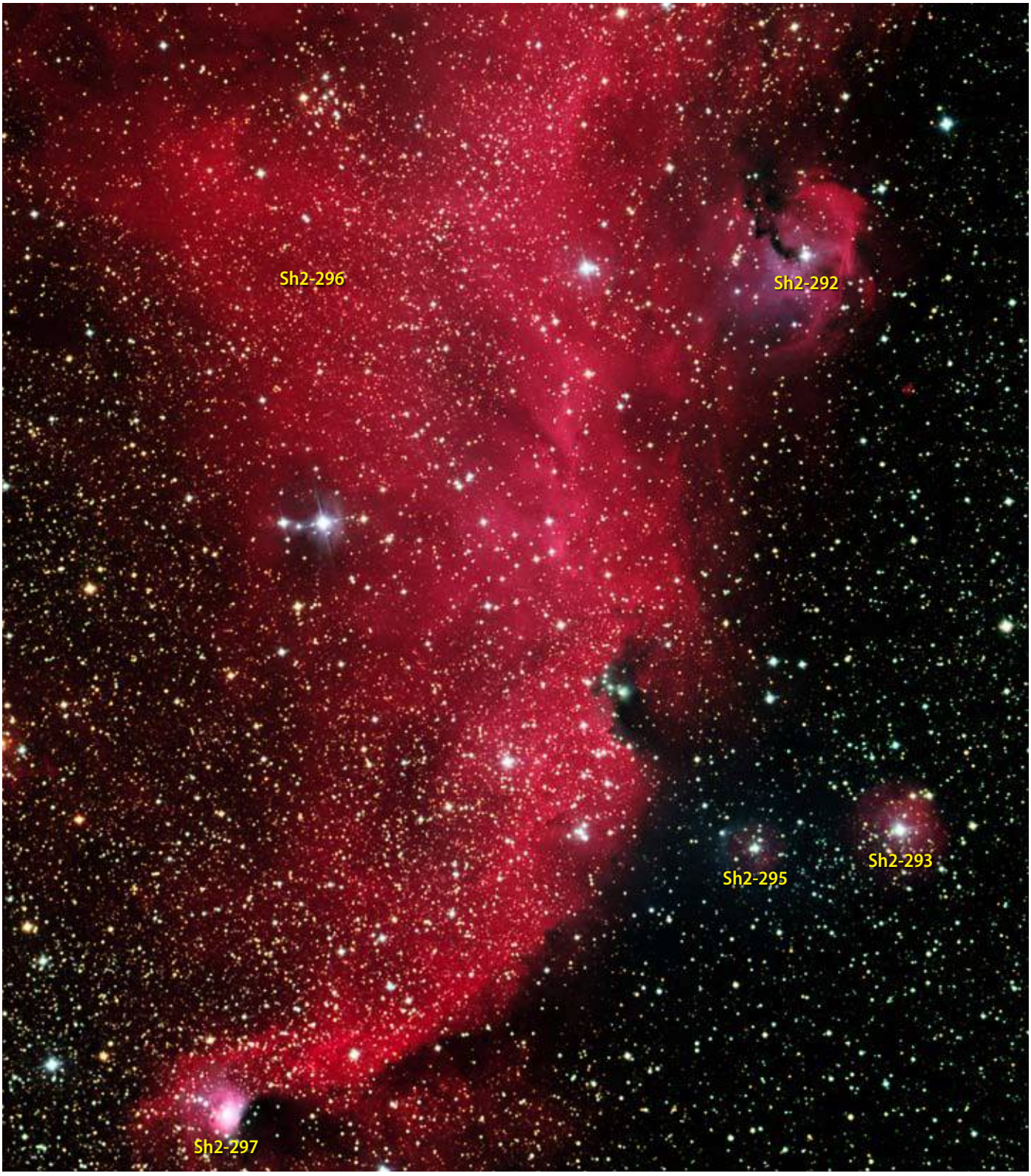
SPIRAL GALAXY NGC 1350 is a member of the Fornax galaxy cluster. It lies about 55 million light-years away and measures roughly 130,000 light-years across, making it a bit larger than our Milky Way. (14.5-inch RC Optical Systems Ritchey-Chrétien telescope at f/9, SBIG ST-10XE CCD camera, LRGB image with exposures of 100, 40, 40, and 40 minutes, respectively) /// **DANIEL VERSCHATSE, ANTILHUE OBSERVATORY, CHILE**





THE MOON OCCULTED SATURN this past March. Fortunately, the imager's house lay along the graze path. At maximum coverage, the Moon's south polar region hid 90 percent of Saturn. (9.25-inch Celestron Schmidt-Cassegrain telescope, Lumenera SKYnyx CCD camera, taken 1) March 2, 2007, at 2h45m UT, 2) 2h53m UT, and 3) 3h01m UT, from Loudwater, Buckinghamshire) /// **DAMIAN PEACH, LOUDWATER, ENGLAND**

THE SEAGULL NEBULA (Sharpless 2–296) in Canis Major is the brightest object in this image. Several other Sharpless objects lie in the area. (6.4-inch Takahashi Epsilon 160 astrograph at f/3.3, SBIG ST-10XME CCD camera, HαRGB image with exposures of 360, 25, 25, and 25 minutes, respectively) /// **DEAN SALMAN, TUCSON, ARIZONA**



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